STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

INTERIM REPORT
ASSESSMENT OF POTENTIAL FISH PASSAGE IMPEDIMENTS ABOVE LAKE OROVILLE'S HIGH WATER MARK
SP-F3.1, Task 1A

OROVILLE FACILITIES RELICENSING
FERC PROJECT NO. 2100

JANUARY 2003

ARNOLD SCHWARZENEGGER
Governor
State of California

MIKE CHRISMAN
Secretary for Resources
The Resources Agency

LINDA S. ADAMS
Interim Director
Department of Water Resources

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

INTERIM REPORT
ASSESSMENT OF POTENTIAL FISH PASSAGE IMPEDIMENTS ABOVE LAKE OROVILLE'S HIGH WATER MARK
SP-F3.1, Task 1A

OROVILLE FACILITIES RELICENSING
FERC PROJECT NO. 2100

This report was prepared under the direction of

Terry J. Mills... Environmental Program Manager I, DWR

by

Paul Bratovich .... Principal/Fisheries Technical Lead, SWRI
Thomas Duster.......................................Associate Environmental Planner/Author, SWRI
Allison Niggemyer ....Associate Environmental Scientist/Author, SWRI
Adrian Pitts..Environmental Scientist/Author, SWRI
David Olson................................Senior Environmental Scientist/Project Manager, SWRI

Assisted by

Becky Fredlund .... Graphics/GIS Technician/ Graphical Support, SWRI

REPORT SUMMARY

The purpose of SP-F3.1 Task 1A is to identify and characterize potential fish passage barriers for inland salmonids, anadromous salmonids and sturgeon upstream of Lake Oroville. Ongoing operation of the Oroville Facilities has the potential to influence accessibility to upstream tributary habitat and the opportunity for interactions between tributary and Lake Oroville fishes. Operations of the Oroville Facilities affect the water surface elevation of Lake Oroville, and the water surface elevation of Lake Oroville influences the ability of Lake Oroville fish to migrate into upstream tributaries. The results of this study will provide information regarding the ability of the fish occurring within Lake Oroville to access habitat upstream of Lake Oroville and to interact with the fish communities in the tributaries upstream from Lake Oroville. Additionally, the results of this study will be used to define the upstream geographic extent of several direct effects study plans including SP-F3.1, SP-F5/7, SP-F8 and SP-F15.

In order to provide a quantitative, repeatable, and defensible assessment of fish passage at potential barriers, a fish passage assessment methodology for salmonids was adapted from Powers and Orsborn (1985) for use in this evaluation. The method utilizes hierarchical decision trees and standard data collection procedures in order to provide a consistent and repeatable evaluation of potential fish passage barriers (Powers and Orsborn 1985). An assessment team of biologists determined the likelihood of passage at each potential upstream migration barrier evaluated for anadromous-sized Chinook salmon, anadromous-sized steelhead, inland-sized Chinook salmon, and inland-sized coho salmon. Due to a lack of knowledge regarding sturgeon swimming and leaping performance metrics, potential for sturgeon passage was not assessed.

Four major and ten minor tributaries of Lake Oroville were surveyed for features with the potential to constitute adult salmonid passage barriers during representative low (October 2002) and high (March 2003) flow conditions. The results of this evaluation are presented in the following summary map of fish passage barriers assessed and their fish passage classification (Figure RS-1). In addition, Table 6-1 provides a physical description for each of the identified fish passage barriers.

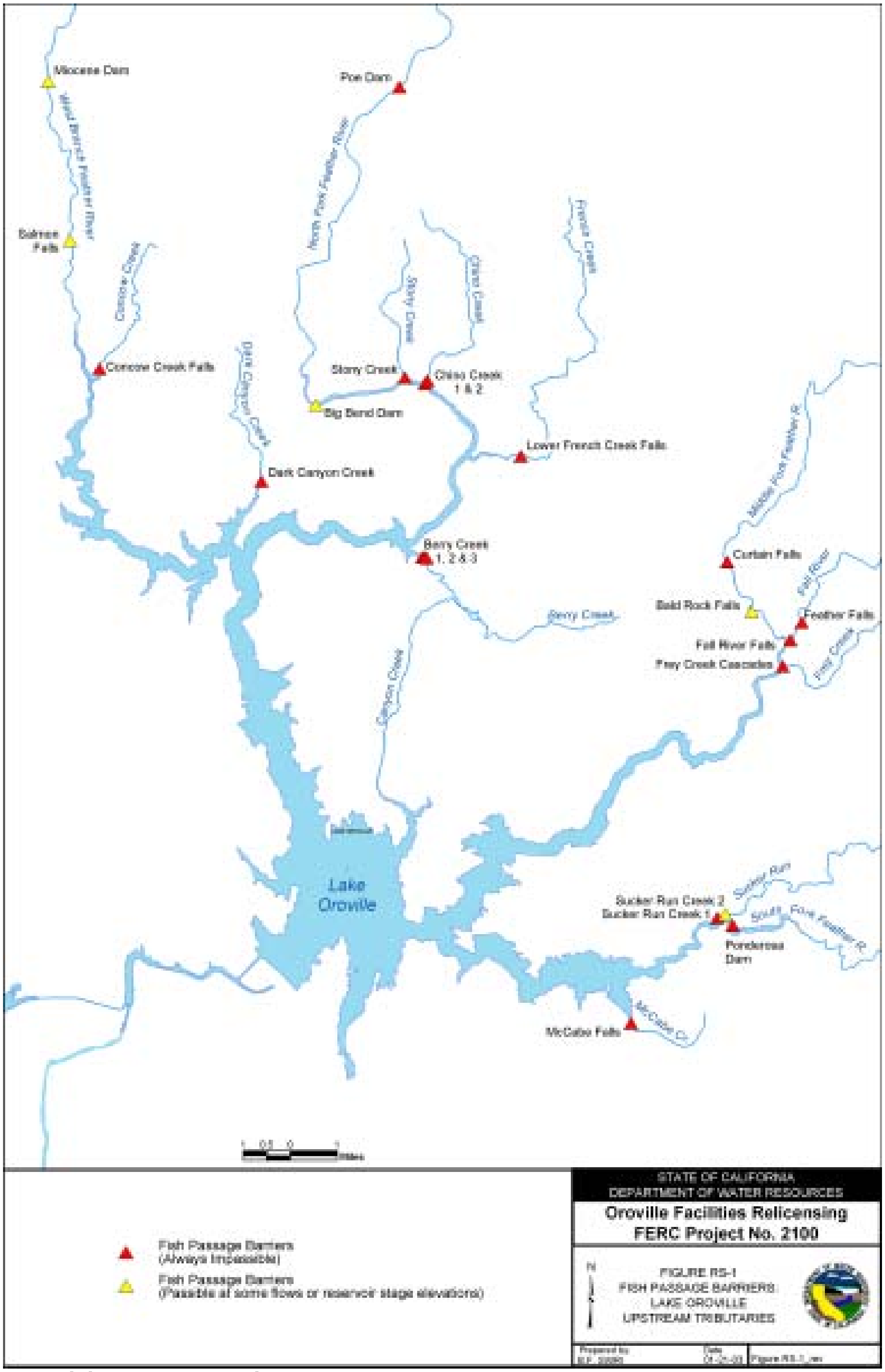


Figure RS-1. Fish Passage Barriers.

Table Of Contents

LIST OF TABLES

LIST OF FIGURES

1.0 INTRODUCTION

1.1 BACKGROUND INFORMATION

Ongoing operation of the Oroville Facilities has the potential to influence accessibility to upstream tributary habitat and the opportunity for interactions between tributary and Lake Oroville fishes. Operations of the Oroville Facilities affect the water surface elevation of Lake Oroville, and the water surface elevation of Lake Oroville influences the ability of Lake Oroville fish to migrate into upstream tributaries. As a component of study plan (SP)-F3.1, *Evaluation of Project Effects on Fish and their Habitat within Lake Oroville, its Upstream Tributaries, the Thermalito Complex, and the Oroville Wildlife Area,* Task 1 of SP-F3.1 characterizes fish habitat and fish species composition in the tributaries upstream from Lake Oroville. Task 1A, herein, identifies and characterizes potential fish passage barriers upstream of Lake Oroville.

1.1.1 Statutory/Regulatory Requirements

The purpose of SP-F3.1 Task 1A is to identify and characterize potential fish passage barriers for inland salmonids, anadromous salmonids and sturgeon upstream of Lake Oroville. Salmonids present in the Feather River include spring-run Chinook salmon (*Oncorhynchus tshawytscha*), fall-run Chinook salmon (*O. tshawytscha*), and steelhead (*O. mykiss*). On September 16, 1999, naturally-spawned Central Valley spring-run Chinook salmon were listed as threatened under the federal Endangered Species Act (ESA) by the Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service (NOAA Fisheries) (NOAA 1999). The Central Valley spring-run Chinook salmon Evolutionarily Significant Unit (ESU) includes all naturally-spawned populations of spring-run Chinook salmon in the Sacramento river and its tributaries, which includes naturally-spawned spring-run Chinook salmon in the Feather River (NOAA 1999). On March 19, 1998, naturally-spawned Central Valley steelhead were listed as threatened under the federal Endangered Species Act (ESA) by NOAA Fisheries (NOAA 1998). The Central Valley steelhead ESU includes all naturally-spawned populations of steelhead in the Sacramento and San Joaquin rivers and their tributaries, which includes naturally-spawned steelhead in the Feather river (NOAA 1998). The results and recommendations from this study fulfill, in part, statutory and regulatory requirements mandated by the ESA as it pertains to Central Valley spring-run Chinook salmon, fall-run Chinook salmon, and steelhead. Hatchery-reared salmonids stocked in Lake Oroville are not considered to be part of the Central Valley ESU.

Green sturgeon (*Acipenser medirostris*) was designated a California Species of Special Concern by the California Department of Fish and Game (DFG) in 1995 (Moyle et al. 1995). DFG’s "Species of Special Concern" status applies to animals not listed under the federal Endangered Species Act or the California Endangered Species Act, but which nonetheless: 1) are declining at a rate that could result in listing; or 2) historically occurred in low numbers and known threats to their persistence currently exist. Species of Special Concern are categorized into one of 4 classes: Class 1 - Endangered or Threatened; Class 2 - Special Concern; Class 3 - Watch List; and Class 4 - Secure. Green sturgeon are listed as a Class 1 Threatened species, meaning that there should be ongoing efforts to protect and enhance this fish population (Moyle et al. 1995). Although not currently listed under the federal ESA, the green sturgeon was recently considered for listing under the federal ESA by NOAA Fisheries. On June 12, 2001, NOAA Fisheries received a petition from the Environmental Protection Information Center, Center for Biological Diversity, and Waterkeepers Northern California regarding the North American green sturgeon, in which the petitioners requested that NOAA Fisheries list this species as either an endangered or threatened species under the ESA (Environmental Protection Information Center et al. 2001). On January 29, 2003, NOAA Fisheries announced its determination that listing green sturgeon under the ESA was not warranted at the time (NOAA 2003). Because of remaining uncertainties about the population structure and status of the species, green sturgeon was added to NOAA Fisheries list of candidate species. NOAA Fisheries will re-evaluate their status in 5 years provided sufficient new information becomes available indicating that a status review update is warranted.

In addition to the ESA, Section 4.51(f)(3) of 18 CFR requires reporting of certain types of information in the Federal Energy Regulatory Commission (FERC) application for license of major hydropower projects, including a discussion of the fish, wildlife, and botanical resources in the vicinity of the project (FERC 2001). The discussion is required to identify the potential impacts of the project on these resources, including a description of any anticipated continuing impact for on-going and future operations.

As a subtask of SP-F3.1, the characterization and assessment of potential fish passage barriers in Task 1A fulfills a portion of the FERC application requirements by detailing the potential effects of project operations on fish passage into upstream tributaries. Additionally, the results of Task 1A of SP-F3.1 define the upstream geographic extent of several direct effects study plans extending upstream of Lake Oroville, and provide information regarding the ability of the fish occurring within Lake Oroville to access habitat upstream of Lake Oroville and to interact with the fish communities in the tributaries upstream from Lake Oroville. In addition to fulfilling these requirements, information collected during this task may be used in developing or evaluating potential Resource Actions.

1.1.2 Study Area

The study area for SP-F3.1 Task 1A includes Lake Oroville and its upstream tributaries extending to the first upstream migration barrier. The area encompassed by Lake Oroville includes areas within the fluctuation zone of Lake Oroville to the high water mark. The upstream tributaries of Lake Oroville consist of four major tributaries: the North Fork Feather River, the West Branch of the North Fork Feather River, the Middle Fork Feather River, and the South Fork Feather River. The upstream extent of the study area extends to the first stream channel obstructions that limit upstream migration of salmonids. Previously described passage barriers including Miocene Dam on the West Branch of the North Fork Feather River, Curtain Falls on the Middle Fork Feather River, Ponderosa Diversion Dam on the South Fork Feather River, and Big Bend Dam on the North Fork Feather River are included in the study area. Smaller tributaries (second order or larger) in the study area include Berry Creek, Canyon Creek, Chino Creek, Concow Creek, Fall River, French Creek, Frey Creek, Sucker Run Creek, McCabe Creek, and Stony Creek.

1.1.2.1 Description

The four main tributaries to Lake Oroville include the North Fork Feather River, West Branch of the North Fork Feather River, Middle Fork Feather River, and South Fork Feather River. Additionally, there are a number of smaller tributaries (tributaries that are second order or larger) evaluated in this task including Berry Creek, Canyon Creek, Chino Creek, Concow Creek, Fall River, French Creek, Frey Creek, Sucker Run Creek, McCabe Creek and Stony Creek. In general, the upstream tributaries can be classified into two types: those above Lake Oroville’s high water mark, and those within the fluctuation zone of Lake Oroville below the high water mark. Below Lake Oroville's high water mark are tributaries that lie within the lakebed. Because these tributaries are within the fluctuation zone of Lake Oroville, the extent of the tributaries falling into this category is dependent upon the water surface elevation of Lake Oroville. When Lake Oroville is at full pool, the tributaries are inundated to the high water mark and are part of Lake Oroville. Under these conditions, the fully inundated reaches of the tributaries loose their riverine characteristics and become lentic in character. When Lake Oroville is not at full pool, tributaries run as streams or rivers until they reach the surface of Lake Oroville, and the tributaries within Lake Oroville's fluctuation zone are exposed. Additionally, this section of the upstream tributaries receives sediment and sand deposits during flood events, and sediment plugs exist as a result of the sediment deposition during the floods of January 1997 and other high flow events. Near the interface of Lake Oroville and its upstream tributaries and in the tributary reaches that are within the fluctuation zone, the fish assemblages are similar to those in Lake Oroville (see Task 2 of SP-F3.1).

The tributaries above Lake Oroville's high water mark are different from those within the fluctuation zone of Lake Oroville because, as described above, they are not seasonally inundated as are the tributaries within the fluctuation zone of Lake Oroville. Habitat in these reaches of the upstream tributaries is similar to mountain trout stream habitat and includes habitat that has the potential to support salmonid spawning and rearing. Generally, the upstream tributaries are managed for coldwater fish species, although flow and water temperature components of the habitat are not controlled by the Oroville Project. Upstream of the high water mark of Lake Oroville, the tributaries support a typical California foothill stream-dwelling fish assemblage, which includes rainbow trout, brown trout, several black bass species such as smallmouth bass, spotted bass, largemouth bass, and redeye bass, hardhead, pikeminnow, and Sacramento sucker. When Lake Oroville is at high water surface elevation (typically in the spring), fish are able to pass over the sediment plugs that exist within the fluctuation zone of Lake Oroville and are able to access the reaches of the tributaries upstream of Lake Oroville's high water mark. When Lake Oroville is at low water surface elevation (typically in the fall), low water levels in the tributaries within the fluctuation zone may be low enough to prevent access to the tributaries above Lake Oroville's high water mark. In this case, fish are not able to access the spawning areas in the regions of the tributaries above Lake Oroville's high water mark. Thus, by controlling water surface elevations in Lake Oroville, project operations have the potential to influence accessibility to upstream tributary fish habitat and the opportunity for potential interactions between tributary and Lake Oroville fish.

Because there are two distinct reaches of upstream tributaries, the areas within the fluctuation zone of Lake Oroville and the areas above Lake Oroville's high water mark, two types of upstream migration barriers are identified through two different types of field surveys. The two types of migration barriers are fundamentally different for several reasons and, therefore, warrant different types of field surveys and evaluations. In the reaches of the tributaries that are above Lake Oroville's high water mark, the migration barriers are generally geologic features, such as waterfalls, or man-made structures, such as dams. Evaluation of the barriers above Lake Oroville's high water mark are the focus of this field investigation and the results of this evaluation are presented herein. In the reaches of the tributaries that are within the fluctuation zone of Lake Oroville and are fully inundated during portions of the year, the sediment plugs resulting from sediment deposition during high flows are the potential upstream migration barriers. Field evaluation of these potential upstream migration barriers will be conducted by SP-G1, and is the focus of a separate evaluation scheduled for completion in December 2003. The assessment of the sediment plugs will be included in the Final Report for SP-F3.1 Task 1A. The sediment plugs are part of a dynamic system which changes more quickly than a geologic feature. Sediment plugs may be stable for a period of several months to a few years depending upon flow, reservoir level fluctuation and duration, rate of sediment deposition, and other factors which will be assessed in SP-G1. A sediment plug that prevents fish passage may be moved during a high flow event or eroded due to tributary flows, thereby eliminating that plug as a potential passage barrier. Additionally, sediment plugs in reaches of the tributaries within the fluctuation zone of Lake Oroville are directly influenced by project operations. For example, when the water surface elevation of Lake Oroville is high, sediment deposits in the uppers reaches of the lake. When lake levels are lowered, sediment is eroded, causing sediments to move. By contrast, waterfalls and dams are stable over a much longer period of time and their stability is generally not influenced by the project. This portion of Task 1A identifies the first upstream migration barrier in each of the tributaries, second order or larger, above the high water mark of Lake Oroville.

The terrain above the high water mark of Lake Oroville is typically steep foothill canyon terrain, and tributaries are generally high gradient streams with typical features including cascades, step pools, and waterfalls. Because of these tributary features, the types of upstream migration barriers initially expected include waterfalls and cascades. In many cases, at the location where the tributary streams join the reservoir, the tributary streams end as waterfalls plunging into the main body of the reservoir. This feature of tributary streams is, in part, dependent upon reservoir elevation, as well as seasonal variations in tributary flow resulting from seasonal rainfall and runoff patterns, or resulting from controlled flow releases from upstream hydroelectric facilities. As a result, the barrier status of any potential upstream migration barrier may vary as a result of reservoir water surface elevation and/or tributary flow.

1.1.2.2 History

Prior to the construction of Oroville Dam, the upstream extent of fish passage was limited by natural fish barriers and previously constructed hydroelectric projects. Although several historical investigations have reported the status of individual fish passage barriers or groups of barriers, we are not aware of any comprehensive, repeatable field-based evaluation of potential fish passage barriers encompassing the entire study area for this task. However, existing historical reports regarding specific features are available. Existing natural and manmade fish barriers were documented in California Department of Water Resources reports (DWR 1993), CDFG fish survey and escapement reports and bulletins (DFG 1952), studies on historical spawning distribution (Yoshiyama et al. 1998), newspaper articles and through local project knowledge of upstream conditions and features (pers. com., E. See, 2001). Information from these existing resources was utilized to construct an initial list of specific features to be targeted during this evaluation, as described below in section 4.0 Methodology.

1.2 DESCRIPTION OF FACILITIES

The Oroville Facilities were developed as part of the State Water Project (SWP), a water storage and delivery system of reservoirs, aqueducts, power plants, and pumping plants. The main purpose of the SWP is to store and distribute water to supplement the needs of urban and agricultural water users in northern California, the San Francisco Bay area, the San Joaquin Valley, and southern California. The Oroville Facilities are also operated for flood management, power generation, to improve water quality in the Delta, provide recreation, and enhance fish and wildlife.

FERC Project No. 2100 encompasses 41,100 acres and includes Oroville Dam and Reservoir, three power plants (Hyatt Pumping-Generating Plant, Thermalito Diversion Dam Power Plant, and Thermalito Pumping-Generating Plant), Thermalito Diversion Dam, the Feather River Fish Hatchery and Fish Barrier Dam, Thermalito Power Canal, Oroville Wildlife Area (OWA), Thermalito Forebay and Forebay Dam, Thermalito Afterbay and Afterbay Dam, and transmission lines, as well as a number of recreational facilities. An overview of these facilities is provided on Figure 1.2-1. The Oroville Dam, along with two small saddle dams, impounds Lake Oroville, a 3.5-million-acre-feet (MAF) capacity storage reservoir with a surface area of 15,810 acres at its normal maximum operating level.

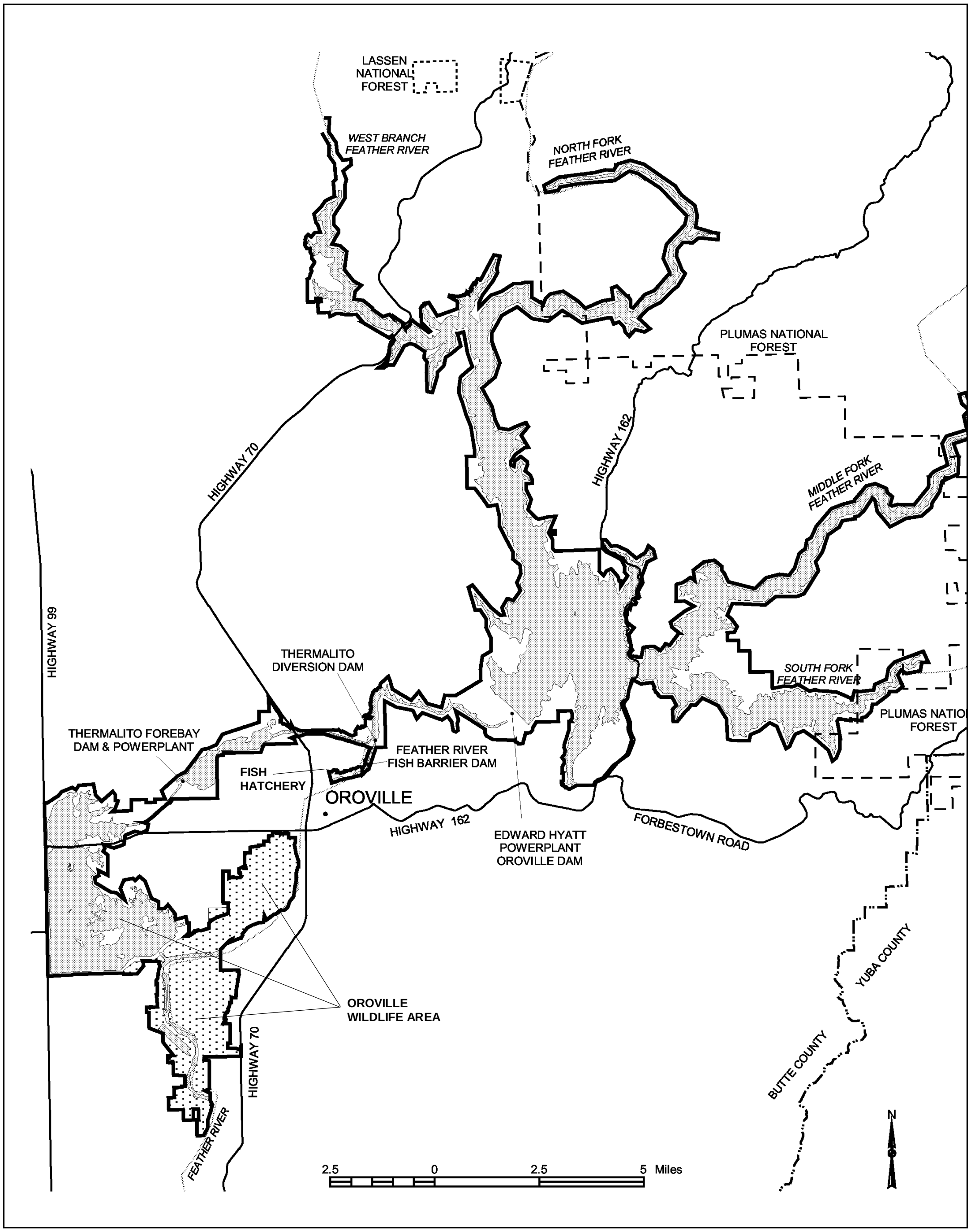


Figure 1.2-1. Oroville Facilities FERC Project Boundary.

The hydroelectric facilities have a combined licensed generating capacity of approximately 762 megawatts (MW). The Hyatt Pumping-Generating Plant is the largest of the three power plants with a capacity of 645 MW. Water from the six-unit underground power plant (three conventional generating and three pumping-generating units) is discharged through two tunnels into the Feather River just downstream of Oroville Dam. The plant has a generating and pumping flow capacity of 16,950 cfs and

5,610 cfs, respectively. Other generation facilities include the 3-MW Thermalito Diversion Dam Power Plant and the 114-MW Thermalito Pumping-Generating Plant.

Thermalito Diversion Dam, four miles downstream of the Oroville Dam, creates a tail water pool for the Hyatt Pumping-Generating Plant and is used to divert water to the Thermalito Power Canal. The Thermalito Diversion Dam Power Plant is a 3-MW power plant located on the left abutment of the Diversion Dam. The power plant releases a maximum of 615 cubic feet per second (cfs) of water into the river.

The Power Canal is a 10,000-foot-long channel designed to convey generating flows of 16,900 cfs to the Thermalito Forebay and pump-back flows to the Hyatt Pumping-Generating Plant. The Thermalito Forebay is an off-stream regulating reservoir for the 114-MW Thermalito Pumping-Generating Plant. The Thermalito Pumping-Generating Plant is designed to operate in tandem with the Hyatt Pumping-Generating Plant and has generating and pump-back flow capacities of 17,400 cfs and 9,120 cfs, respectively. When in generating mode, the Thermalito Pumping-Generating Plant discharges into the Thermalito Afterbay, which is contained by a 42,000-foot-long earth-fill dam. The Afterbay is used to release water into the Feather River downstream of the Oroville Facilities, helps regulate the power system, provides storage for pump-back operations, and provides recreational opportunities. Several local irrigation districts receive water from the Afterbay.

The Feather River Fish Barrier Dam is downstream of the Thermalito Diversion Dam and immediately upstream of the Feather River Fish Hatchery. The flow over the dam maintains fish habitat in the low-flow channel of the Feather River between the dam and the Afterbay outlet, and provides attraction flow for the hatchery. The hatchery was intended to compensate for spawning grounds lost to returning salmon and steelhead trout from the construction of Oroville Dam. The hatchery can accommodate an average of 15,000 to 20,000 adult fish annually.

The Oroville Facilities support a wide variety of recreational opportunities. They include: boating (several types), fishing (several types), fully developed and primitive camping (including boat-in and floating sites), picnicking, swimming, horseback riding, hiking, off-road bicycle riding, wildlife watching, hunting, and visitor information sites with cultural and informational displays about the developed facilities and the natural environment. There are major recreation facilities at Loafer Creek, Bidwell Canyon, the Spillway, North and South Thermalito Forebay, and Lime Saddle. Lake Oroville has two full-service marinas, five car-top boat launch ramps, ten floating campsites, and seven dispersed floating toilets. There are also recreation facilities at the Visitor Center and the OWA.

The OWA comprises approximately 11,000-acres west of Oroville that is managed for wildlife habitat and recreational activities. It includes the Thermalito Afterbay and surrounding lands (approximately 6,000 acres) along with 5,000 acres adjoining the Feather River. The 5,000 acre area straddles 12 miles of the Feather River, which includes willow and cottonwood lined ponds, islands, and channels. Recreation areas include dispersed recreation (hunting, fishing, and bird watching), plus recreation at developed sites, including Monument Hill day use area, model airplane grounds, three boat launches on the Afterbay and two on the river, and two primitive camping areas. California Department of Fish and Game's (DFG) habitat enhancement program includes a wood duck nest-box program and dry land farming for nesting cover and improved wildlife forage. Limited gravel extraction also occurs in a number of locations.

1.3 CURRENT OPERATIONAL CONSTRAINTS

Operation of the Oroville Facilities varies seasonally, weekly and hourly, depending on hydrology and the objectives DWR is trying to meet. Typically, releases to the Feather River are managed to conserve water while meeting a variety of water delivery requirements, including flow, temperature, fisheries, recreation, diversion and water quality. Lake Oroville stores winter and spring runoff for release to the Feather River as necessary for project purposes. Meeting the water supply objectives of the SWP has always been the primary consideration for determining Oroville Facilities operation (within the regulatory constraints specified for flood control, in-stream fisheries, and downstream uses). Power production is scheduled within the boundaries specified by the water operations criteria noted above. Annual operations planning is conducted for multi-year carry over. The current methodology is to retain half of the Lake Oroville storage above a specific level for subsequent years. Currently, that level has been established at 1,000,000 acre-feet (af); however, this does not limit draw down of the reservoir below that level. If hydrology is drier than expected or requirements greater than expected, additional water would be released from Lake Oroville. The operations plan is updated regularly to reflect changes in hydrology and downstream operations. Typically, Lake Oroville is filled to its maximum annual level of up to 900 feet above mean sea level (msl) in June and then can be lowered as necessary to meet downstream requirements, to its minimum level in December or January. During drier years, the lake may be drawn down more and may not fill to the desired levels the following spring. Project operations are directly constrained by downstream operational constraints and flood management criteria as described below.

1.3.1 Downstream Operation

An August 1983 agreement between DWR and DFG titled, "*Agreement Concerning the Operation of the Oroville Division of the State Water Project for Management of Fish & Wildlife*," sets criteria and objectives for flow and temperatures in the low flow channel and the reach of the Feather River between Thermalito Afterbay and Verona. This agreement: (1) establishes minimum flows between Thermalito Afterbay Outlet and Verona which vary by water year type; (2) requires flow changes under 2,500 cfs to be reduced by no more than 200 cfs during any 24-hour period, except for flood management, failures, etc.; (3) requires flow stability during the peak of the fall-run Chinook spawning season; and (4) sets an objective of suitable temperature conditions during the fall months for salmon and during the later spring/summer for shad and striped bass.

1.3.1.1 Instream Flow Requirements

The Oroville Facilities are operated to meet minimum flows in the lower Feather River as established by the 1983 agreement (see above). The agreement specifies that Oroville Facilities release a minimum of 600 cfs into the Feather River from the Thermalito Diversion Dam for fisheries purposes. This is the total volume of flows from the diversion dam outlet, diversion dam power plant, and the Feather River Fish Hatchery pipeline.

Generally, the instream flow requirements below Thermalito Afterbay are 1,700 cfs from October through March, and 1,000 cfs from April through September. However, if runoff for the previous April through July period is less than 1,942,000 af (i.e., the 1911-1960 mean unimpaired runoff near Oroville), the minimum flow can be reduced to 1,200 cfs from October to February, and 1,000 cfs for March. A maximum flow of 2,500 cfs is maintained from October 15 through November 30 to prevent spawning in overbank areas that might become de-watered.

1.3.1.2 Water Temperature Requirements

The Diversion Pool provides the water supply for the Feather River Fish Hatchery. The hatchery objectives are 52°F for September, 51°F for October and November, 55°F for December through March, 51°F for April through May 15, 55°F for last half of May, 56°F for June 1-15, 60°F for June 16 through August 15, and 58°F for August 16-31. A temperature range of plus or minus 4°F is allowed for the objectives extending from April through November.

There are several temperature objectives for the Feather River downstream of the Afterbay Outlet. During the fall months, after September 15, the temperatures must be suitable for fall-run Chinook salmon. From May through August, they must be suitable for shad, striped bass, and other warmwater fish.

The National Marine Fisheries Service has also established an explicit criterion for steelhead and spring-run Chinook salmon. Memorialized in a biological opinion on the effects of the Central Valley Project and SWP on Central Valley spring-run Chinook salmon and steelhead as a reasonable and prudent measure, DWR is required to maintain daily average water temperature of < 65^{o} F at Feather River Mile 61.6 (Robinson Riffle in the low flow channel) from June 1 through September 30. The requirement is not intended to preclude pump-back operations at the Oroville Facilities needed to assist the State of California with supplying energy during periods when the California ISO anticipates a Stage 2 or higher alert.

The hatchery and river water temperature objectives sometimes conflict with temperatures desired by agricultural diverters. Under existing agreements, DWR provides water for the Feather River Service Area (FRSA) contractors. The contractors claim a need for warmer water during spring and summer for rice germination and growth (i.e., 65°F from approximately April through mid May, and 59°F during the remainder of the growing season). There is no obligation for DWR to meet the rice water temperature goals. However, to the extent practical, DWR does use its operational flexibility to accommodate the FRSA contractor's temperature goals.

1.3.1.3 Water Diversions

Monthly irrigation diversions of up to 190,000 (July 2002) af are made from the Thermalito Complex during the May through August irrigation season. Total annual entitlement of the Butte and Sutter County agricultural users is approximately 1 MAF. After meeting these local demands, flows into the lower Feather River continue into the Sacramento River and into the Sacramento-San Joaquin Delta. In the northwestern portion of the Delta, water is pumped into the North Bay Aqueduct. In the south Delta, water is diverted into Clifton Court Forebay where the water is stored until it is pumped into the California Aqueduct.

1.3.1.4 Water Quality

Flows through the Delta are maintained to meet Bay-Delta water quality standards arising from DWR's water rights permits. These standards are designed to meet several water quality objectives such as salinity, Delta outflow, river flows, and export limits. The purpose of these objectives is to attain the highest water quality, which is reasonable, considering all demands being made on the Bay-Delta waters. In particular, they protect a wide range of fish and wildlife including Chinook salmon, Delta smelt, striped bass, and the habitat of estuarine-dependent species.

1.3.2 Flood Management

The Oroville Facilities are an integral component of the flood management system for the Sacramento Valley. During the wintertime, the Oroville Facilities are operated under flood control requirements specified by the U.S. Army Corps of Engineers (USACE). Under these requirements, Lake Oroville is operated to maintain up to 750,000 af of storage space to allow for the capture of significant inflows. Flood control releases are based on the release schedule in the flood control diagram or the emergency spillway release diagram prepared by the USACE, whichever requires the greater release. Decisions regarding such releases are made in consultation with the USACE.

The flood control requirements are designed for multiple use of reservoir space. During times when flood management space is not required to accomplish flood management objectives, the reservoir space can be used for storing water. From October through March, the maximum allowable storage limit (point at which specific flood release would have to be made) varies from about 2.8 to 3.2 MAF to ensure adequate space in Lake Oroville to handle flood flows. The actual encroachment demarcation is based on a wetness index, computed from accumulated basin precipitation. This allows higher levels in the reservoir when the prevailing hydrology is dry while maintaining adequate flood protection. When the wetness index is high in the basin (i.e., wetness in the watershed above Lake Oroville), the flood management space required is at its greatest amount to provide the necessary flood protection. From April through June, the maximum allowable storage limit is increased as the flooding potential decreases, which allows capture of the higher spring flows for use later in the year. During September, the maximum allowable storage decreases again to prepare for the next flood season. During flood events, actual storage may encroach into the flood reservation zone to prevent or minimize downstream flooding along the Feather River.

2.0 NEED FOR STUDY

As a subtask of SP-F3.1, *Evaluation of Project Effects on Fish and their Habitat within Lake Oroville, its Upstream Tributaries, the Thermalito Complex, and the Oroville Wildlife Area*, the characterization and assessment of potential fish passage barriers in Task 1A fulfills a portion of the FERC application requirements by detailing the potential effects of project operations on fish passage into upstream tributaries. Additionally, the results of Task 1A of SP-F3.1 define the upstream geographic extent of several direct effects study plans extending upstream of Lake Oroville, and provides information regarding the ability of the fish occurring within Lake Oroville to access habitat upstream of Lake Oroville and to interact with the fish communities in the tributaries upstream from Lake Oroville. In addition to fulfilling these requirements, information collected during this task may be used in developing or evaluating potential Resource Actions.

Ongoing operation of the Oroville Facilities has the potential to influence accessibility to upstream tributary habitat and the opportunity for interactions between tributary and Lake Oroville fishes. Task 1 of SP-F3.1 characterizes fish habitat and fish species composition in the tributaries upstream from Lake Oroville. Task 1A, herein, identifies and characterizes potential fish passage barriers upstream of Lake Oroville. Task 1B describes fish species composition in Lake Oroville's upstream tributaries, while Task 1C characterizes fish habitat in Lake Oroville's upstream tributaries from Lake Oroville's high water mark to the identified migration barrier. For further description of Tasks 1B or 1C relating to Lake Oroville's upstream tributaries, see SP-F3.1 and associated interim and final reports. In addition to providing information for use in Tasks 1B and 1C, Task 1A of SP-F3.1 also provides the definition of the geographic scope of potential direct project effects for other study plans and data collection efforts including SP-F5/7, SP-F8, SP-F15, SP-F3.1, SP-G1 and SP-W6.

3.0 STUDY OBJECTIVES

3.1 STUDY APPLICATION

The objective of SP-F3.1 Task 1A is to identify and characterize potential fish passage barriers for inland salmonids, anadromous salmonids and sturgeon upstream of Lake Oroville. The results of this identification will determine the upper boundary of the geographic study area for a number of direct effects Fisheries study plans supporting the Oroville Facilities FERC Relicensing effort including SP-F3.1, SP-F5/7, SP-F8, and SP-F15. Data collected in this task serves as a foundation for future evaluations and development of potential Resource Actions.

3.1.1 Department of Water Resources

The information from Task 1A of SP-F3.1 will be used by DWR and the Environmental Work Group (EWG) to define the geographic scope of potential direct project effects for other study plans and data collection efforts including SP-F5/7, SP-F8, SP-F15, SP-F3.1, SP-G1 and SP-W6. Additionally, data collected in this task serve as a foundation for future evaluations and development of potential Resource Actions.

3.1.2 Other Studies

As a subtask of SP-F3.1, *Evaluation of Project Effects on Fish and their Habitat within Lake Oroville, its Upstream Tributaries, the Thermalito Complex, and the Oroville Wildlife Area*, Task 1 of SP-F3.1 characterizes fish habitat and fish species composition in the tributaries upstream from Lake Oroville. Task 1A, herein, identifies and characterizes potential fish passage barriers upstream of Lake Oroville. Task 1B describes fish species composition in Lake Oroville's upstream tributaries, while Task 1C characterizes fish habitat in Lake Oroville's upstream tributaries from Lake Oroville's high water mark to the identified migration barrier. For further description of Tasks 1B or 1C relating to Lake Oroville's upstream tributaries, see SP-F3.1 and associated interim and final reports. In addition to providing information for use in Tasks 1B and 1C, Task 1A of SP-F3.1 will also provide the definition of the geographic scope of potential direct project effects for other study plans and data collection efforts including SP-F5/7, SP-F8, SP-F15, SP-F3.1, SP-G1 and SP-W6.

3.1.3 Engineering Exhibits

No modeling results from DWR's Engineering and Operations Group were necessary to complete this study plan report because SP-F3.1 Task 1A required potential fish passage barriers to be identified under current operating conditions.

3.1.4 Environmental Documentation

In addition to Section 4.51(f)(3) of 18 CFR, which requires reporting of certain types of information in the FERC application for license of major hydropower projects, it may be necessary to satisfy the requirements of NEPA and ESA. Because FERC has the authority to grant an operating license to DWR for continued operation of the Oroville Facilities, discussion is required to identify the potential impacts of the project on many types of resources, including fish, wildlife, and botanical resources. In addition, NEPA requires discussion of any anticipated continuing impact from on-going and future operations. To satisfy NEPA and ESA, DWR is preparing a Preliminary Draft Environmental Assessment (PDEA) to attach to the FERC license application, which will include information provided by this study plan report.

3.1.5 Settlement Agreement

In addition to statutory and regulatory requirements, SP-F3.1 Task 1A could provide information to aid in the development of potential Resource Actions to be negotiated during the collaborative process. Also, information obtained from analysis of the fish passage barriers could be used by the collaborative to negotiate operating procedures.

4.0 METHODOLOGY

The methodology used to conduct field surveys to characterize and evaluate potential fish passage barriers upstream of Lake Oroville's high water mark closely follows the methodology originally in SP-F3.1 Task 1A. A detailed description of the methods used to assess potential fish passage impediments, and to characterize identified potential fish passage barriers, are presented below.

4.1 FISH PASSAGE BARRIERS ASSESSMENT METHODOLOGY

4.1.1 Selection of core methodology

A variety of fish passage assessment methodologies were reviewed and examined in order to determine if any existing fish passage assessment methodology contained the elements necessary for the Oroville Facilities Relicensing Fish Passage Assessment Methodology mentioned above. Existing fish passage assessment methods were evaluated for elements including a foundation based on quantitative fish performance metrics, the flexibility that would allow evaluation of a variety of types of fish passage barriers, and the ability to allow evaluation of inland-sized and anadromous-sized salmonids. Although many of the reviewed fish passage assessment methodologies provided a only a single criterion for evaluation of a fish passage barrier, such as required pool depth or maximum jump height, the fish passage assessment methodology described by Powers and Orsborn (1985) was rigorous enough to consider a wide variety of physical passage metrics, and to allow evaluation of several distinct types of barriers. Because the method described was based on quantitative fish performance metrics, was capable of evaluating a variety of types of barriers, was flexible enough to support evaluation of several sizes of fish, and was capable of allowing passage evaluation under potentially altered site conditions, this method was chosen as the framework for the Oroville Facilities Relicensing Fish Passage Assessment Methodology and was confirmed by the project collaborative in the approval of the detailed study plan (Powers and Orsborn 1985).

This assessment methodology was chosen because it is:

- a consistent, repeatable and defensible assessment of fish passage;
- based on published literature and quantitative fish performance metrics;
- capable of evaluating a variety of types of barriers;
- flexible enough to support evaluation of several sizes of fish;
- adjustable (i.e., if a defined variable is changed, calculations can recomputed to determine the passability at a potential barrier under different assumptions);
- capable of allowing passage evaluation under potentially altered site conditions; and
- not dependent upon having the same observers at each potential barrier.

4.1.2 Description of Oroville Facilities Relicensing Fish Passage Assessment Methodology

The fundamentals of the Oroville Facilities Relicensing Fish Passage Assessment Methodology are based upon the assessment methodology of Powers and Orsborn (1985). The fish performance metrics (i.e., leaping curves), the requirements for physical site characterization, the formulas used in calculations of variables, and the mechanisms for decision-making regarding barrier passability are taken directly from Powers and Orsborn (1985). Although the elements described above are embedded within the text of the Powers and Orsborn (1985) methodology, the decision trees and data sheets included in the Oroville Facilities Relicensing Fish Passage Assessment Methodology represent a synthesis and reorganization of the materials originally presented by Powers and Orsborn (1985) that is concise and easy to use when working in the field. Additionally, several variables used in fish passage calculations, such as fish length and fish body depth, were defined using data specific to the Feather River when such data were available. The values assigned to these variables, as well as the sources of information used to assign the values to these variables, are detailed below in the section titled "Structure and Use of Data Sheets".

4.1.2.1 Barrier Type Characterization

The Oroville Facilities Relicensing Fish Passage Assessment Methodology utilized the analytical methodology and passage criteria set forth by Powers and Orsborn (1985). Two main components to this analysis exist. The first component, barrier typing, involved the classification of a potential fish passage barrier as either a falls, chute, or cascade, as defined by Powers and Orsborn (1985). Falls were characterized by steep (commonly vertical) overflow sections where the impact of the falling water scours a deep plunge pool at the foot of the falls. Falls form elevation barriers where the difference in water surface elevation between the upstream water surface and the plunge pool, and/or the horizontal distance from the falls crest to the plunge pool, exceeds the leaping capabilities of the pertinent fish species. At fall-type barriers, leaping efficiency of the fish is constrained by unfavorable plunge pool condition (i.e., depth, turbulence) and even if leaping is successful, the fish can be swept back due to high velocities and/or shallow depths above the falls' crest. Two conceptual images of falls are illustrated below in Figures 4.1-1 and 4.1-2.

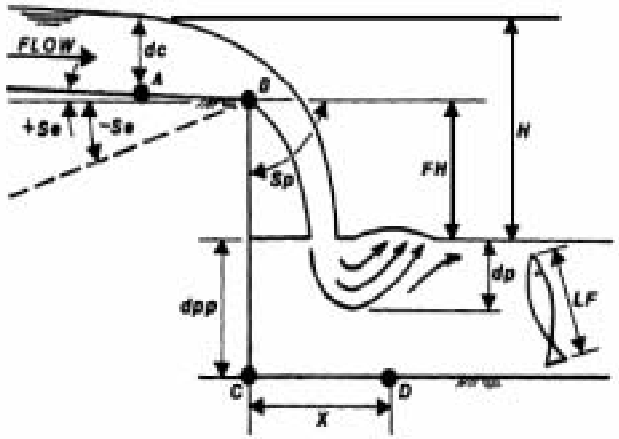


Figure 4.1-1. Conceptual model of falls.
Note: A = point on fish exit bed slope where critical depth occurs; B = elevation of crest; C = furthest point upstream on bed of plunge pool; D = point just downstream of falling water (or standing wave) on bed of plunge pool; Se = fish exit slope; Sp = fish passage slope; dc = critical depth (point A); dpp = depth in the plunge pool; dp = depth the falling water plunges; X = horizontal distance from the crest (point B) to standing wave (point D); FH = fall height; H = change in water surface elevation; LF = length of fish
(source: Powers and Orsborn (1985).

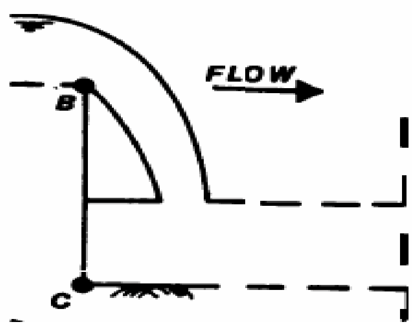


Figure 4.1-2. Simplified diagram of a falls.
(source: Powers and Orsborn (1985).

A chute was characterized by steep, sloping, rough open channels, offering the fish a high velocity medium in which to swim without a resting area. Chutes form velocity barriers where the water velocity near the downstream entrance to the chute exceeds the fish's swimming speed. At chute-type barriers, if the downstream plunge pool is shallow, the standing wave may form too far downstream for the fish to rest before bursting into the chute. Even if the velocities down in the chute are within the fish's swimming speed, the depth of flow and slope length could prohibit passage. Additionally, chutes often pass a bulked mass of water and entrained air. Entrained air results in reduced swimming efficiency due to reduced propulsive power of the fish's tail and buoyancy of the fish. Two different representations of chutes are provided in Figures 4.1-3 and 4.1-4, below.

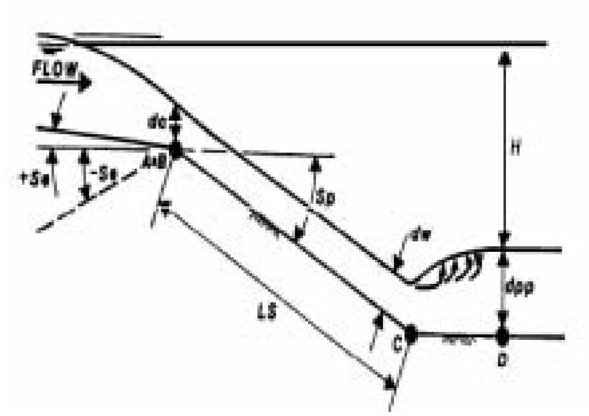


Figure 4.1-3. Conceptual model of a chute.
Note: A = point on fish exit bed slope where critical depth occurs; B = elevation of crest; C = furthest point upstream on bed of plunge pool; D = point just downstream of standing wave (or hydraulic jump) on bed of plunge pool; Se = fish exit slope; LS = length of slope; Sp = fish passage slope; dc = critical depth (point A); dw = depth of water; dpp = depth in the plunge pool; H = change in water surface elevation
(source: Powers and Orsborn (1985).

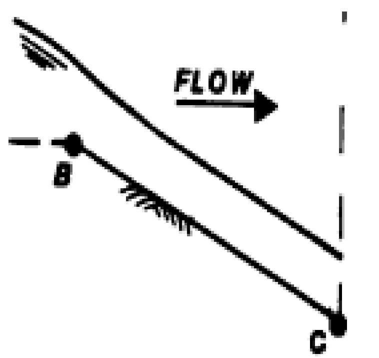


Figure 4.1-4. Simplified diagram of a chute.
(source: Powers and Orsborn (1985).

Cascades are usually located in areas with steep topography (canyons) and are very difficult to survey because of the constraints on physical access, high velocities, deep pools and turbulence. Cascades often present fish with high velocities, excessive turbulence and orientation challenges which make it impossible for a fish to effectively use all its swimming power. If the roughness elements (or boulders) are large, they will often create periodic resting areas within the cascading reach. A pictorial representation of a cascade is provided in Figure 4.1-5.

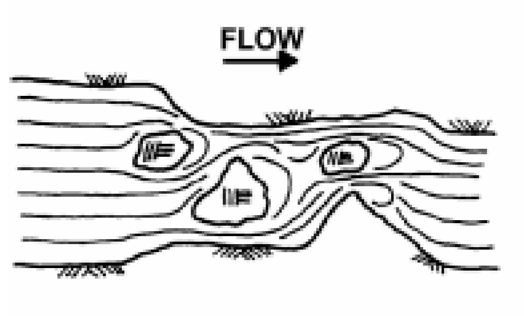


Figure 4.1-5. Simplified diagram of a cascade.
(source: Powers and Orsborn (1985).

Two types of cascades were defined: boulder cascades and turbulent cascade. A boulder cascade was characterized as a reach of stream with large boulders or jutting rocks that obstruct and/or churn the flow into violently turbulent white water. Boulder cascades may consist of boulders in the stream that are large enough to provide resting areas for the fish in their wakes. A turbulent cascade was characterized as a reach of stream with excessive velocities and excessive turbulence, resulting in upwellings, eddies, entrained air and vortices. Typically in turbulent cascades, the excessive velocities and excessive turbulence is enough to obstruct passage. Turbulence serves to deflect a swimming fish from its course, causing it to expend energy to resist up-wellings, eddies, entrained air, and vortices. In a turbulent cascade, most of the fish's energy is utilized simply to maintain position and direction at the foot of a high velocity obstacle.

In some cases, barriers can be combinations of falls and chutes, and illustrated in Figure 4.1-6.

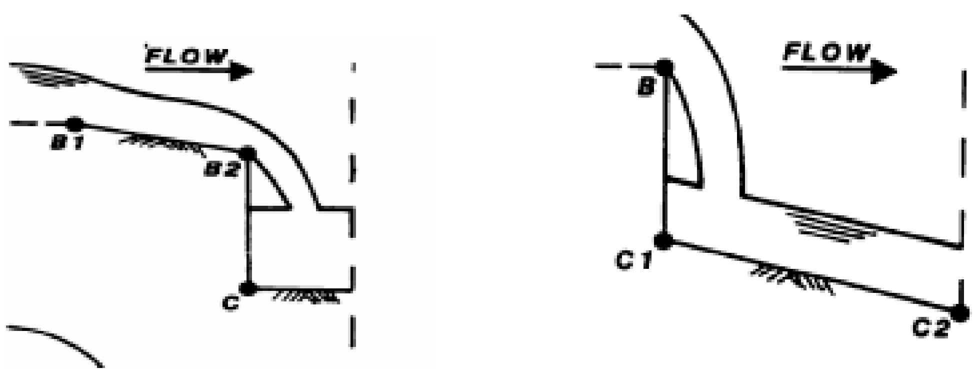


Figure 4.1-6. Simplified diagram of combination-type barriers such as chute-falls (left) and falls-chute (right).
(source: Powers and Orsborn (1985).

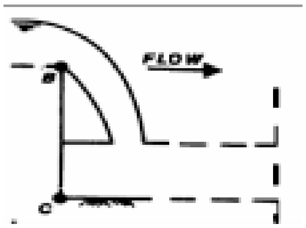
The decision tree for barrier typing, presented below in Figure 4.1-7, was utilized to classify the type of potential barriers to upstream migration as falls, chutes, boulder cascades, or turbulent cascades. The barrier classification was then used select the specific type of assessment method (falls assessment, chute assessment, boulder cascade assessment, or turbulent cascade assessment) required to evaluate fish passage. One advantage provided by this analytical method was that different types of barriers in any combination could be evaluated by isolating each component of the combination-barrier, beginning with the downstream-most potential barrier. In the case of a chute-falls, the falls would be analyzed using the falls assessment methodology, and if the falls is determined to be passable, the chute would be analyzed using the chute assessment methodology.

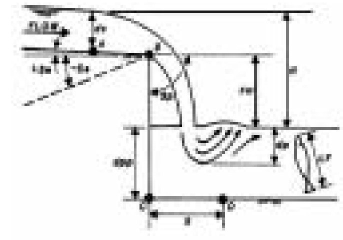
4.1.2.2 Decision Tree Construction and Utilization

Once the type of barrier was identified, the specific decision tree for passage assessment for the appropriate barrier type was utilized to assess passage. For each barrier type (falls, chutes, boulder cascades, and turbulent cascades), a passage assessment decision tree was constructed by extracting the relevant analytical components and decision elements from the Powers and Orsborn (1985) methodology. The decision trees are designed to simplify the assessment process by sequencing decision making so that only one specific decision is made at a time. Each step in the passage assessment decision tree is a "yes or no" question that is clearly stated, and based on quantitative metrics. Decision tree questions logically break down the barrier into its separate physical component parts, allowing a systematic, repeatable, and comparable evaluation of each potential barrier. An advantage to sequentially evaluating the components of each barrier is that if the answer to the first decision tree question suggests that a barrier is impassible, the evaluation is terminated and additional questions need not be addressed to determine barrier passability.

To illustrate the function of the passage assessment decision tree, consider the first step of the falls passage assessment decision tree (illustrated below in Figure 4.1-8) as if Feather Falls were being evaluated as a potential fish passage barrier. The question is: "Is the vertical change in water surface elevation (H) greater than the maximum height of fish's leap (HL) where $\theta L = 90°$?" In other words, the first step in the falls decision tree asks whether the height of the barrier is greater than the maximum height a fish could jump if it jumped straight up in the air. In the case of Feather Falls, the height is approximately 640 ft, which is clearly greater than the height any fish would be expected to jump. Thus, the answer to the first question in the decision tree is "yes". Powers and Orsborn (1985) suggest that for falls-type barriers, if the height of the barrier is greater than the distance a fish could jump if it jumped straight up in the air, then the barrier is impassible because the barrier is too high (i.e., classified as an elevation barrier). Thus, Feather Falls would be determined to be a barrier to fish passage on the basis of the height of the falls, as represented in the falls passage assessment decision tree in Figure 4.1-8.

1. Based on the physical characteristics of this potential barrier, is it defined as a falls?





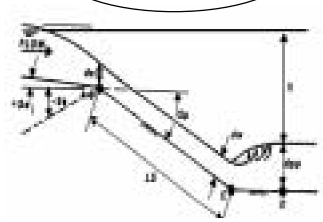
Conceptual model of a fall, where:
A = point on fish exit bed slope where critical depth occurs; B = elevation of crest; C = furthest point upstream on bed of plunge pool; D = point just downstream of falling water (or standing wave) on bed of plunge pool; S_e = fish exit slope; S_p = fish passage slope; d_c = critical depth (point A); d_{pp} = depth in the plunge pool; d_p = depth the falling water plunges; X = horizontal distance from the crest (point B) to standing wave (point D); FH = fall height; H = change in water surface elevation; LF = length of fish

- characterized by steep (commonly vertical) overflow sections where the impact of the falling water scours a deep plunge pool at the foot of the falls

Yes → Proceed with **Falls Passage Assessment**

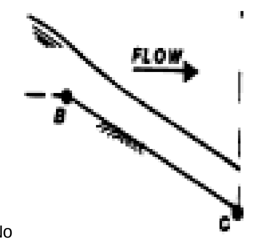
No →

2. Based on the physical characteristics of this potential barrier, is it defined as a chute?



Conceptual model of a chute, where:
A = point on fish exit bed slope where critical depth occurs; B = elevation of crest; C = furthest point upstream on bed of plunge pool; D = point just downstream of standing wave (or hydraulic jump) on bed of plunge pool; S_e = fish exit slope; LS = length of slope; S_p = fish passage slope; d_c = critical depth (point A); d_w = depth of water; d_{pp} = depth in the plunge pool; H = change in water surface elevation

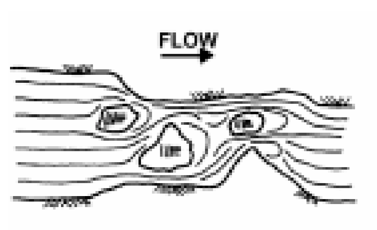
- characterized by steep, sloping, rough open channels, offering the fish a high velocity medium in which to swim without resting area



Yes → Proceed with **Chute Passage Assessment**

No →

3. Based on the physical characteristics of this potential barrier, is it defined as a cascade?



- characterized as a reach of stream with large boulders or jutting rocks that obstruct the flow

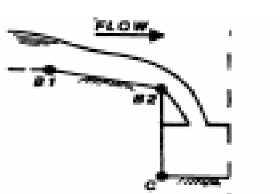
Yes → To determine the type of cascade barrier, measurement of bed slopes and pools depths are required. If such measurements can be made, then the cascade simply consists of a series of falls and/or chutes

No → Return to Step 1: Reassess barrier, determine whether it is more fall-like or chute-like

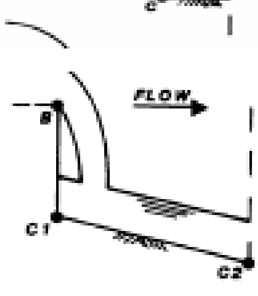
4. Are pools and slopes easily measurable?

Yes → Determine whether the cascade is a chute/fall or a fall/chute, or a series of combinations and proceed with the appropriate passage assessment(s), beginning with the downstream-most feature

Chute/fall



Fall/chute



No → Does cascade consist of boulders in the stream that are large enough to provide resting areas for fish in their wakes?

No → Proceed with **Turbulent Cascade Passage Assessment**

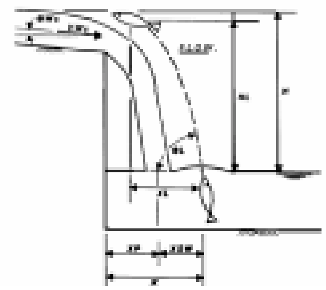
Yes → Proceed with **Boulder Cascade Passage Assessment**

Figure 4.1-7. Decision tree for barrier typing utilized to classify the type of potential barriers as falls, chutes, boulder cascades, or turbulent cascades

1. Is the vertical change in water surface elevation (H) greater than the maximum height of fish's leap (HL) where θL = 90°?

Yes → **Stop: Elevation barrier**

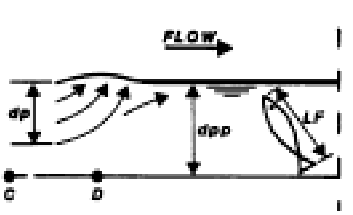
No → 2. Is the horizontal distance from the crest of the falls to the standing wave (X) greater than the horizontal distance of the fish's leap at the highest point of the leap (XL)?



Yes → 3. Does superimposition of the water surface profile on fish leaping curves suggest that the barrier is passable?

No → **Stop: Horizontal distance barrier**

Yes → 4. Is the depth of penetration of the falling water (dp) greater than the depth of the plunge pool (dpp) (i.e., does the falling water impact the bottom of the plunge pool)?



Yes → Conditions not optimal for leaping. Reevaluate passability considering effects of turbulence in disorienting fish under sub-optimal plunge pool conditions (e.g., estimate percentage leaping capacity reduction). Is barrier considered passable following reevaluation based on effects of turbulence alone?

No → **Stop: Plunge pool barrier**

Yes → 5. Is the length of the fish (LF) greater than the depth of the plunge pool (dpp)?

Yes → Conditions not optimal for leaping. Reevaluate passability considering effects of reduced propulsive power of fish's tail under sub-optimal plunge pool conditions (e.g., estimate percentage leaping capacity reduction). Is barrier considered passable following reevaluation based on reduced propulsive power alone?

No → **Stop: Plunge pool barrier**

Yes → Calculate the maximum leaping angle if the fish submerges itself fully and superimpose the leaping angle on the leaping curves

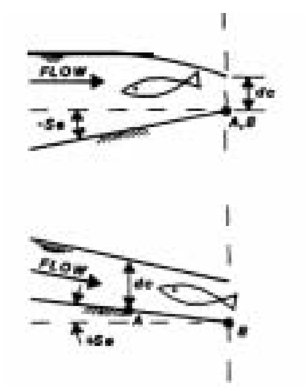
→ 6. Using best professional judgment, is it the opinion of the team that the total sum effects on fish (turbulence, reduced propulsive power, and reduced angle from Step 5) resulting from sub-optimal plunge pool conditions still result in the potential barrier being considered passable?

No → **Stop: Plunge pool barrier**

Yes → 7.

(Step 5) No → 7.

7. Is the exit slope at the landing condition (S_e) positive or negative?



Positive → 8. Is critical depth (d_c) located too far upstream for fish to reach during landing?

Yes → Landing conditions should be analyzed as a chute (See Steps 1-4 in Chute Passage Assessment)

No → 9.

Negative → d_c is at crest. Measure or calculate d_c and V_c. → 9.

9. Is $d_f > d_c$?

Yes → Conditions not optimal for propulsion upon landing. Reevaluate passability considering effects of reduced propulsive power of fish's tail under sub-optimal landing conditions (e.g., estimate percentage propulsion capacity reduction). → Is the mean velocity at critical depth (V_c) > the sustained fish swimming speed (VFS)?

No → Is the mean velocity at critical depth (V_c) > the sustained fish swimming speed (VFS)?

Yes → Landing conditions should be analyzed as a chute (See Steps 1-4 in Chute Passage Assessment)

No → 10. Is the combined effect of the total percentage of reduced leaping (Step 6), the re-evaluation conclusions incorporating turbulence, propulsion, and leaping angle (Step 6), and the percentage reduced propulsion (Step 9) enough combined reduction in leaping capability and propulsion to suggest that the potential barrier is still passable?

Yes → **Passable**

No → **Impassable**

Figure 4.1-8. Falls passage assessment decision tree.

If the answer to the first question in the decision tree had been “no”, answering a sequence of additional questions could have been required in order to evaluate potential barrier passability. However, in the example of Feather Falls, additional steps in the falls passage assessment need not be taken to determine if Feather Falls is a fish passage barrier because of the sequential nature of the decision process initially presented by Powers and Orsborn (1985). Each step in the passage assessment decision tree for each barrier type is designed to be executed sequentially until the result of “Stop” or “Passable” is reached. In cases where the barrier was determined to be impassible, the barrier can be classified according to the limiting passage factor (i.e., elevation, horizontal distance, plunge pool, distance, or velocity), which may aid in identification of potential PM&E opportunities.

4.1.2.3 Structure and Use of Data Sheets

In the example of Feather Falls presented above, only the height of the falls needed to be measured to determine that the falls is a barrier to fish passage on the basis of the height of the falls. If the answer to the first question in the passage assessment decision tree (Figure 4.1-7) had been “no”, answers to additional questions would have been required. Answering additional questions would have required collection of a variety of additional data in order to evaluate potential barrier passability. However, in the example of Feather Falls, additional metrics do not need to be collected to determine if Feather Falls is a fish passage barrier because of the sequential nature of the decision process initially presented by Powers and Orsborn (1985). This eliminates the inefficiency of collecting data characterizing metrics that are potentially not required in order to complete the evaluation of fish barrier passability.

In the above example of Feather Falls, the answer to the first question of the decision tree was straightforward because clearly no fish could jump the height of the falls (in this case, 640 ft). However, in most cases, the answer is not so obvious. For example, what if the falls had only been 3.5 ft in height? This would require additional calculations to determine whether a specific species of fish could vertically jump 3.5 ft. The data sheets associated with each passage assessment decision tree provide the information required to perform the required calculations to answer each question in the decision trees.

In order to make each decision represented in the decision tree for any given barrier type, various metrics that physically characterize the potential barrier are required. Each decision tree is accompanied by a data sheet that describes the metrics and decisions required to complete the fish passage assessment. Additionally, the data sheets provide the calculations required to arrive at the answer to each question on each passage assessment decision tree. As with the passage assessment decision trees, the data sheets guide the assessment in a sequential fashion. The data sheets are designed to simplify the field assessment process by sequencing data collection so that only the data required to make one specific decision are collected. The data required to make the next decision are not collected until the previous decision has been made. A detailed description of the types of metrics used in the data sheets is provided below, followed by an example illustrating the use of data sheets.

A variety of types of metrics are required for use in the data sheet. Physical metrics characterize the attributes of each barrier and may include barrier height, horizontal distance component of barrier, plunge pool depth, and water velocity. Another type of metric utilized in the fish passage assessment process is a calculated metric. Calculated metrics are metrics that describe an attribute that is typically difficult to measure directly, but can be easily calculated using other metrics. Equations for calculated metrics are provided in the data sheets. An example of a calculated metric would be slope, which is calculated after measuring the horizontal and vertical component of a barrier using the equation slope = vertical (m or ft) /horizontal (m or ft). A third class of metrics, variables that require definition prior to analysis, are metrics that are determined through a literature review or review of site-specific data sets from other scientific studies. For this analysis, the variables that required definition prior to analysis included the coefficient of fish condition, length of fish, depth of fish (body depth), and fish speed. In order to determine the numerical value assigned to each of these variables for use in the data sheet calculations, literature and data sets from DWR's Feather River Studies program were reviewed. The definition of each variable as described by Powers and Orsborn (1985) and the rationale for assignment of a numerical value to each variable will be discussed separately below. With assigned variables such as these, the variable can be changed and the calculations can recomputed to determine the passability at a potential barrier under a different set of assumptions than those presented in this analysis.

4.1.2.4 Coefficient of fish condition

The coefficient of fish condition is a measure of the condition of the fish. The assessment methodology utilizes a coefficient of fish condition to adjust the performance capabilities of the fish for their condition at the time of passage and the corresponding reduction in their swimming speeds and leaping abilities. To determine actual values of these percentages, a study was conducted on coho and chum salmon swimming up a high velocity chute at Johns Creek Fish Hatchery near Shelton, Washington. From this study, it was concluded that most of the time the salmon were swimming at 50%, 75%, or 100% of their maximum burst speeds, depending on the condition of the fish (Bell 1973). These percentages were therefore used by Powers and Orsborn (1985) to define coefficient of fish condition (Cfc). Descriptions of fish condition and associated values for Cfc are given below in Table 4.1-1.

Table 4.1-1. Description of fish condition and associated numeric value for Cfc.

Coefficient of fish condition (Cfc)	
Fish Condition	**Coefficient (Cfc)**
Bright; fresh out of salt water or still a long distance from spawning grounds; spawning colors not yet developed	1.00
Good; in the river for a short time; spawning colors apparent but not fully developed; still migrating upstream	0.75
Poor; in the river for a long time; full spawning colors developed and fully mature; very close to spawning grounds	0.50

(source: Powers and Orsborn (1985).

Because SP-F3.1 Task 1A requires analysis of anadromous-sized Chinook salmon, anadromous-sized steelhead, inland-sized Chinook salmon and inland-sized coho salmon, numerical valuates for Cfc were developed for all four species. For anadromous-sized salmonids, migration rates and migration distance to potential barriers were used to develop a numerical recommendation for Cfc. Migration rates for adult Chinook salmon have been reported in free-flowing rivers at 15-31 km/day (Bjornn and Reiser 1991), as cited in (Dauble and Mueller 1993), and have been reported in free-flowing rivers at up to 24 km/d (Oregon Fish Commission 1960), as cited in (Dauble and Mueller 1993). The median migration rates for radio-tagged steelhead was 31.5 km/d (range 17.0-45.4 km/d) for studies on the Snake River, 32.8 km/d for studies on the lower Columbia River, and 34.9 km/d for a study of steelhead migration through the mid-Columbia River (English et al. 2001). It is approximately 200 miles (325 km) from San Francisco Bay to the Fish Barrier Dam on the Feather River, which represents the present extent of upstream migration for anadromous salmonids. The barriers to be assessed in this task are 5 – 10 miles upstream of the fish barrier dam and no estimate of the impact of capture, handling and transport or of the passage alternatives over the Oroville Dam have been included in the estimation of the condition factor. Assuming that adult Chinook salmon and steelhead are migrating at the upper end of reported migration rates in the Columbia River system, it would take adult steelhead approximately 10 days to migrate the necessary 200 miles (assuming a migration rate of 34.9 km/day). Likewise, it would take adult Chinook salmon approximately 11 days (assuming a migration rate of 31 km/day) to migrate the required 200 miles. Given the definitions of the coefficients of fish condition in Table 4.1-1, the "good" condition (Cfc = 0.75) appears to be the most reasonable descriptor of the condition of adult salmonids migrating upstream in the Feather River. The “good” condition factor was recommended by the assessment team as a conservative rating factor, and was approved by the collaborative team members for use in the analysis of anadromous-sized Chinook salmon and steelhead.

With respect to inland-sized salmon (Chinook salmon and coho salmon), Chinook salmon and coho salmon stocked in Lake Oroville should be expected to be in excellent condition given that they do not have to travel far to reach the upstream migration barriers, and given that no additional handling for transport is necessary for fish that are stocked in Lake Oroville. Given the definitions of the coefficients of fish condition above, the "bright" condition (Cfc = 1.00) appears to be the most reasonable descriptor of the condition of adult salmonids stocked in Lake Oroville and therefore was chosen for the analysis of inland-sized Chinook salmon and coho salmon.

4.1.2.5 Length of fish and depth of fish

When possible, length data from the Feather River, Lake Oroville, or other northern California river systems was used as the basis for the fish length utilized in the calculations. The length of fish used in Powers and Orsborn's (1985) passage assessment is total length. Body depth is the depth of the fish's body (i.e., vertical measurement) at the insertion of the dorsal fin. Rationale for selection of numerical values used in the passage assessment for length of fish and depth of fish are presented below for each of the four sizes of fish analyzed.

Size data from anadromous-sized Feather River Chinook salmon were used to calculate numeric values for length and depth of fish variables. Adult male Chinook salmon returning to spawn in the Feather River range in fork length from 34 to 120 cm, with a mean fork length of 87.2 cm (DWR 1983). Using morphometric proportions, the fork length (FL) was converted in total length (TL), using the equation FL = 96.7%TL, and total length was related to depth of fish (df) using the equation df = 21.5%TL (Froese and Pauly 2002b). The total fish length and fish depth were calculated using the uppermost value for fork length (120 cm) because larger fish have the fastest burst speeds, and therefore represent the individuals with the greatest leaping capacity.

Total fish length (TL) = 120 cm/0.967 = 124.1 cm (4.07 ft)
Fish depth (df) = 124.1 cm(0.215) = 26.7 cm (0.88 ft or 10.5 inches)

Size data from inland-sized Lake Oroville Chinook salmon were used to calculate numeric values for length and depth of fish variables. In a study completed by DWR in Lake Oroville between 1993 and 1999, 1,371,901 coded wire tagged Chinook salmon were released and 2,037 were recovered during the study (DWR 1999). The average total length (TL) of Chinook recovered was approximately 54 cm, while the maximum observed length was approximately 71 cm. As above, total fish length and fish depth were calculated using the uppermost value for fork length (71 cm) because larger fish have the fastest burst speeds, and therefore represent the individuals with the greatest leaping capacity. Using the above morphometric proportions, the following values were calculated for TL and df for inland Chinook salmon.

TL = 71 cm (2.3 ft)
df = (71 cm)(.215) = 15.3 cm (6.01 inches)

In the absence of length data specific to the Feather River or other comparable inland river system describing steelhead length, the upper end of the length range for adult steelhead described for California fishes (Moyle 2002) was used to calculate length and depth of steelhead. Steelhead adults range in size from 35-65 cm FL (Moyle 2002). As with Chinook salmon, fish length (TL) and fish depth were calculated using the uppermost value for fork length (65 cm) because larger fish have the fastest burst speeds, and therefore represent the individuals with the greatest leaping capacity. Morphometric proportions suggest that FL = 97.17% TL and that df = 21.36% TL. The following values were calculated for TL and df for adult steelhead.

TL = 65 cm/0.9717 = 66.9 cm (2.19 feet or 26.3 inches)
df = 0.2136 * 66.9 cm = 14.3 cm (5.63 inches)

Because coho salmon are being stocked for the first time in Lake Oroville this season, no length data on Lake Oroville coho are available. Length information for coho was not readily obtainable for other California reservoirs. In the absence of reservoir data, length data from anadromous coho was utilized, knowing that reservoir coho are likely to be smaller than are anadromous coho. As a result, if a barrier is determined to be impassible to anadromous coho, it therefore is also not passable by smaller, inland-sized coho salmon with lesser leaping capacity. Spawning anadromous coho adults typically measure 40-70 cm FL (DFG 2002). As with Chinook salmon, total fish length and fish depth were calculated using the uppermost value for fork length (70 cm) because larger fish have the fastest burst speeds, and therefore represent the individuals with the greatest leaping capacity. Using morphometric proportions, FL = 97.9% TL and df = 24.9% TL (Froese and Pauly 2002a). Therefore, the following values were calculated for coho in the absence of length data for reservoir-grown coho.

TL = 70cm/0.979 = 71.5 cm (2.3 feet or 28.1 inches)
df = 71.5*0.249 = 17.8 cm (7.0 inches)

The calculated fish length and fish depth will overestimate the ability of inland coho salmon to pass a barrier because reservoir-grown coho are not expected to achieve sizes as large as ocean-grown coho salmon.

4.1.2.6 Fish speed

Fish speeds potentially used in this analysis are grouped into 3 categories: sustained, prolonged, and burst speed, as defined by Hoar and Randall (Hoar and Randall 1978), as cited in (Powers and Orsborn 1985). Sustained speeds are defined as speed that allow normal functions without fatigue. Prolonged speeds are defined as activities lasting 15 seconds to 200 minutes, which result in fatigue, and burst speeds are defined as activities which cause fatigue in 15 seconds or less. Powers and Orsborn (1985) base the swimming speed on the speeds described by Bell (1973), which are presented in the table below (Table 4.1-2). Powers and Orsborn (1985) and Bell (1973) recommend a 10 second burst speed duration, or time to fatigue. For anadromous-sized adult Chinook salmon and steelhead, the uppermost range of the reported speed in each category was chosen for analysis, thereby representing the individuals with the greatest leaping capacity. Thus, the burst speed used in this analysis for anadromous-sized adult Chinook salmon was 22.4 fps and the burst speed for anadromous-sized adult steelhead was 26.5 fps.

Table 4.1-2. Fish speeds of average size adult anadromous salmon and steelhead.

Fish Speed (fps)			
Species	**Sustained**[b]	**Prolonged**[b]	**Burst**
Steelhead	0 - 4.6	4.6 - 13.7	13.7 - 26.5
Chinook	0 - 3.4	3.4 - 10.8	10.8 - 22.4
Coho	0 - 3.4	3.4 - 10.6	10.6 - 21.5
Sockeye	0 - 3.2	3.2 - 10.2	10.2 - 20.6
Pink & Chum[a]	0 - 2.6	2.6 - 7.7	7.7 - 15.0

[a] Pink & Chum salmon values estimated from leap heights of 3 to 4 ft at waterfalls
[b] Called cruising and sustained, respectively, in Bell (1973).

Source: (Bell 1973)

Because fish speeds for inland-sized salmon were not reported by Bell (1973), numerical values for burst speeds for inland-sized salmon were calculated. Because burst speed is affected by fish length (Hunter and Mayor 1986), as cited in (Alaska Department of Fish and Game and Alaska Department of Transportation and Public Facilities 2001) and because inland salmon are not as large as anadromous salmon, the burst speed for inland salmon was calculated for the appropriate fish length using the following formulas (Hunter and Mayor 1986), as cited in (Alaska Department of Fish and Game and Alaska Department of Transportation and Public Facilities 2001), where TL is total length and t is swimming effort duration in seconds (10 seconds, as recommended in (Bell 1973) and (Powers and Orsborn 1985). TL used was that determined as the appropriate TL measurement for inland coho and Chinook salmon (see above). Sustained speed could be calculated for inland salmonids using a similar formula, but because the duration of the swimming effort for sustained speeds could be infinite, no calculation was made, and the sustained speeds for anadromous salmonids were used (if required) as the sustained speeds for inland salmonids.

Chinook salmon:
$$\text{Burst speed} = (11.49)((TL)^{0.32})t^{-0.5}$$
$$\text{Burst speed} = (11.49)((.71m)^{0.32})10s^{-0.5}$$
$$\text{Burst speed} = 3.26 \text{ m/s} = 10.7 \text{ fps}$$

Coho salmon:
$$\text{Burst speed} = (13.3)((TL)^{0.52})t^{-0.65}$$
$$\text{Burst speed} = (13.3)((.715m)^{0.52})10s^{-0.65}$$
$$\text{Burst speed} = 2.5 \text{ m/s} = 8.2 \text{ fps}$$

In addition to measured metrics, calculated metrics, and variables that require definition through literature review or other data collection, one other class of metric is used by Powers and Orsborn (1985), interpreted metrics. Interpreted metrics are those that require comparison with a graphical feature. An example of this type of metric is the superimposition of the water surface profile of a barrier onto the leaping curves provided in Powers and Orsborn (1985) to determine whether or not a barrier is passable based on the horizontal and vertical component of the leap required to clear the barrier. Step 3 of the falls passage assessment (Figure 4.1-7) requires an interpreted metric, such as use of leaping curves. By superimposing the height and range (i.e., horizontal component) of the leap required to clear a barrier over the leaping curve for the appropriate fish species, it is possible to determine whether or not the leap would be feasible given the burst speed of the fish. The leaping curves are built using physics-based projectile equations which assume the burst speed of Chinook salmon, steelhead, and coho salmon is that reported by Bell (1973) (22.4 fps for Chinook salmon and 26.5 fps for steelhead). Because the analysis of anadromous-sized salmonids utilizes Bell's burst speed, these graphs are applicable to the analysis of anadromous-sized Chinook salmon and steelhead. Inland-sized Chinook salmon and coho would have a lesser leaping capacity than illustrated on the provided leaping curves because their smaller total length results in lower burst speed as calculated above (inland-sized Chinook salmon = 10.7 fps and coho salmon = 8.2 fps). Therefore, a barrier that is not passable by anadromous-sized salmonids is also not passable for inland-sized salmonids. However, a barrier that is passable by anadromous-sized salmonids may not be passable for inland-sized salmonids. If necessary, leaping curves can be re-created for inland-sized Chinook salmon and coho salmon using equations provided in the data sheets.

In order to illustrate how the data sheets, types of metrics, and decision trees work together to provide a consistent, repeatable and defensible assessment of fish passage, an example of the first three steps in the falls passage assessment is provided. Although each step for each barrier type is different and involves different equations, it is not reasonable to summarize all of them in the methods section of this report. For additional information regarding derivation of equations, see Powers and Orsborn (1985).

For example, assume a potential fall-type barrier is to be evaluated for passage of adult anadromous steelhead just leaving the ocean at the beginning of upstream migration. Step 1 of the falls passage assessment (Figure 4.1-8) asks, "Is the vertical change in water surface elevation (H) greater than the maximum height of fish's leap (HL) where $\theta L = 90°$?" In order to determine the answer to this question in a consistent, repeatable and quantitative fashion, consult the data sheet for fall-type barriers (Figure 4.1-8). According to the data sheet, 5 metrics are required to answer this question. The first metric, the coefficient of fish condition, a variable defined prior to analysis. The description suggests that the appropriate condition of the fish is "bright", or Cfc=1.0 (Table 4.1-1). The second metric required is the burst speed of the fish (VFB) and is also a variable defined prior to analysis. The burst speed of an adult anadromous steelhead is approximately 26.5 fps (Table 4.1-2). The third metric, the fish speed (VF), is a calculated metric. The data sheet illustrates that this metric is calculated by multiplying the Cfc (1.0) by the VFB (26.5 fps). Thus, 1.0*26.5 fps = 26.5 fps. In this case, the speed of the fish, or VF, is its burst speed because the fish is in good condition. The fourth metric, the height a specific fish can leap, is also calculated. In order to calculate the height the steelhead can leap (HL), use the equation provided in the data sheet: $HL = (VF(\sin \theta L))^2/2g$, where g is the force of gravity (32.2 ft/sec^2). The angle of the jump (θL) is defined as 90° in the question associated with the first step of the falls passage assessment (Figure 4.1-8, Step 1). In other words, how high can the fish jump if it jumps straight up in the air. In this case, the adult anadromous-sized steelhead with a Cfc=1.0 can jump 10.9 ft [HL = $(26.5 \text{ ft/sec}(\sin 90°))^2/2*32.2 \text{ ft/sec})$]. The last metric required is the height of the potential barrier and is the only metric measured in the field necessary for step 1. Consider two possibilities, barrier A, measuring 5.1 ft. high, and barrier B, measuring 10.5 ft high. The steelhead can clear either barrier by jumping straight in the air and attaining a height of 10.9 ft. Therefore, the result in an answer of "no" for step 1 of the falls passage assessment (Figure 4.1-8).

An answer of "no" in step 1 sends the analyst to step 2 (Figure 4.1-8). Step 2 asks, "Is the horizontal distance from the crest of the falls to the standing wave (X) greater than the horizontal distance of the fish's leap at the highest point of the leap (XL)?" The distance from the crest of the falls to the standing wave (X) is measured for barrier A and barrier B at 10.2 ft. The data sheet (Figure 4.1-9) provides a method for calculating X if it cannot easily be measured, but this is not required because X has been measured in the field in this case.

The calculated metric in the next equation is the angle of the jump (θL) required given the height and range of the barrier. The height was measured in step 1 (barrier A = 5.1 ft, and barrier B= 10.5 ft). The range was measured in the field at 10.2 ft for both barriers. Using the equation $\theta L = \tan^{-1}[3(H/X)]$, the angle of the jump required for barrier A is 56.3°, while that required for barrier B is 72.1°. The final portion of step 2 calculates the horizontal distance of the fish's leap at the highest point of the leap (XL). Using the provided equation [$XL = VF^2(\cos \theta L)(\sin \theta L/g)$] and values for metrics calculated or measured prior to this step, the horizontal distance of the fish's leap at the highest point of it's jump is 10.1 ft from the take-off point, or XL = $(26.5 \text{ ft/sec})^2(\cos 56.3°)(\sin 56.3°/32.2 \text{ ft/sec})$ = 10.1 ft. For barrier B, XL = $(26.5 \text{ ft/sec})^2(\cos 72.1°)(\sin 72.1°/32.2 \text{ ft/sec})$ = 6.4 ft. Thus, the answer to step 2 is "yes" because the horizontal distance from the crest of the falls to the standing wave (in both cases 10.2 ft) is greater than the distance of the fish's leap at the highest point of the leap (barrier A = 10.1 ft; barrier B = 6.4 ft).

A "yes" answer provides the opportunity to use an interpreted metric to answer step 3 of the falls passage assessment (Figure 4.1-8). Step 3 asks, "Does superimposition of the water surface profile on fish leaping curves suggest that the barrier is passable?" By using the leaping curve presented in Figure 4.1-10, the profile of the barrier can be superimposed on the leaping curve for steelhead. Using the solid line in the figure representing a steelhead of Cfc = 1.0, the X and H coordinates can be marked for each barrier. For both barriers, the horizontal distance of the fish's leap at the highest point of the leap (i.e., at the arc of the curve) is less than the horizontal distance to the crest of the falls.

River name________________________________
Barrier name________________________________
Photo numbers____________________________ Date:________________________
Barrier location (lat/long)______________________ Video footage_____________________________
Approximate flow:_______________

Metric	Metric type	Anadromous-sized salmon		Inland-sized Salmon	
	L=from literature C=calculate M=measure E=estimate I = interpret	Chinook salmon	Steelhead	Chinook salmon	Coho salmon
Step 1					
C_{fc}	E	0.75	0.75	1.0	1.0
VFB	L	22.4 fps	26.5 fps	10.7 fps	8.2 fps
VF	C: $VF = VFB*C_{fc}$				
HL	C: $HL = (VF(\sin\theta L))^2/2g$				
H	M				
Step 2					
X	M				
	C: C or M "XP": $XP = VW_c[\cos(\theta W_c)]t$				
	C: If C: M VW_c				
	C: If C: M θW_c				
	C: If C: C "t": $H = [VW_c(\sin\theta W_c)]t - (1/2)gt^2$				
	C: M XSW				
	C: X = XP+XSW				
θL	C: $\theta L = \tan^{-1}[3(H/X)]$				
XL	C: $XL = VF^2(\cos\theta L)(\sin\theta L/g)$				
Step 3					
S_p	C: $S_p = H/XP$				
Water Surface Profile	I: Map H,L, S_p over leaping curves	Pass./Impass.	Pass./Impass.	Pass./Impass.	Pass./Impass.
Step 4					
dp	M				
dpp	M				
% reduced leaping	E				
Re-evaluation conclusions incorporating % reduced leaping due to turbulence	E	Pass./Impass.	Pass./Impass.	Pass./Impass.	Pass./Impass.
Step 5					
LF	E/L/C	124.1 cm	66.9 cm	71 cm	71.5 cm
% reduced leaping	E				
Re-evaluation conclusions incorporating % reduced leaping due to reduced propulsive power	E	Pass./Impass.	Pass./Impass.	Pass./Impass.	Pass./Impass.
θL	C: $\theta L = \sin^{-1}(dpp/LF)$				
Compare θL to maps from Step 3	I				
Step 6					
Total % reduced leaping	C: Total % reduced leaping = % reduced leaping from Step 4 + % reduced leaping from Step 5				
Re-evaluation conclusions incorporating turbulence, propulsion, and leaping angle (from Step 5)	E	Pass./Impass.	Pass./Impass.	Pass./Impass.	Pass./Impass.
Step 7					
S_e	M or E	Positive/negative			
d_c	M, E, or C				
	If C: M: channel cross-section (d, W, A)				
	If C: C: For rectangles: $Q = 5.7(W)(d_c)^{1.5}$				
	If C: C: For triangles: $Q = [2(d_c)^{2.5}]S$				
	If C: C: Total Q as a function of d_c				
	If C: E: Q				
	If C: C: d_c for estimated Q				
V_c	M or C				
	If C: $V_c = Q_{(total)}/A$				
Step 8					
Locate d_c	C: M: mean depth of flow upstream of crest				
	C: M: bed elevation				
	C: M: cross-sectional area				
	C: M: top width of channel				
	C: C: $Z = Q/(g)^{0.5}$				
	C: C: pool elevation = bed elevation + measured depth of flow + hydraulic depth/Z				
	M: pool elevation upstream of crest where water is quite				
	If pool elevation (measured) = pool elev. (calc.), d_c occurs at point where depth of flow was measured — location of d_c				
	If pool elevation (measured) > pool elev. (calc.), move farther upstream and recalculate — location of d_c				

Metric	Metric type	Anadromous-sized salmon		Inland-sized Salmon	
Compare location of d_c to maps from Step 3	I: Is d_c too far upstream for fish to reach during landing?	Yes/No	Yes/No	Yes/No	Yes/No
Step 9					
d_f	E	26.7 cm	14.3 cm	15.3 cm	17.8 cm
% reduced propulsion	E				
% propulsion capability	C: % propulsion capability = 1 - % reduced propulsion				
VFS_{lit}	L	3.4 fps	4.6 fps	3.4 fps	3.4 fps
VFS	C: VFS = (VFS_{lit})(% propulsion capability)				
Step 10					
Combined % reduced abilities	C: Combined % reduced abilities = Total % reduced leaping from Step 6 + % reduced propulsion from Step 9				
Final evaluation		Pass./Impass.	Pass./Impass.	Pass./Impass.	Pass./Impass.

Data collected and witnessed by ____

____

____

____

____

____

____

____

Figure 4.1-9. Data sheet for fall-type barriers.

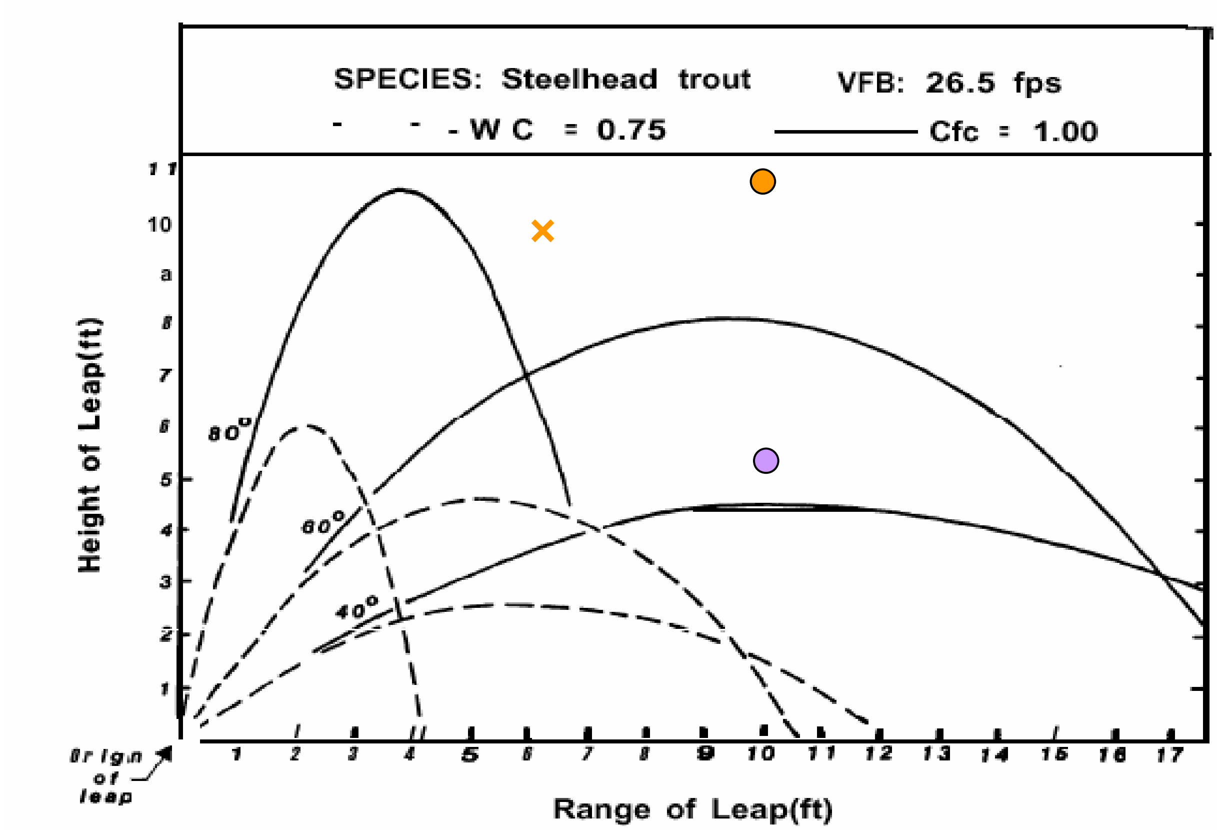


Figure 4.1-10. Steelhead leaping curves with the horizontal and vertical components of two potential barriers superimposed.
Note: Barrier A = purple circle; Barrier B = orange circle; Jump height of steelhead jumping at an angle of 72.1° = orange X.

However, graphical interpretation illustrates that in the case of barrier A (Figure 4.1-10, purple circle), where the horizontal distance of the fish's leap at the highest point of the leap (10.1 ft) is nearly the horizontal distance of the crest of the wave (10.2 ft), the steelhead will be able to leap clearly over the barrier. Provided the plunge pool and landing conditions are sufficient, the fish will be able to pass the barrier. Thus, for barrier A, the answer to step 3 is "yes", and the analysis can continue to step 4, taking required plunge pool, slope and velocity measurements as directed. In the case of barrier B (Figure 4.1-10, orange circle), the angle of the jump (72.1°) results in the fish reaching the highest point in the leaping arc at a horizontal distance of 6.4 ft. A horizontal distance of 6.4 ft is not sufficient to reach the barrier at a horizontal distance of 10.2 ft, as illustrated in Figure 4.1-10. In fact, at a horizontal distance of 6.4 ft and a jump angle of 72.1°, the height at the top of the arc would be only 9.9 ft, as represented by the orange X in Figure 4.1-10. Envisioning a parabola drawn with its center at the orange X in Figure 4.1-10 illustrates that the steelhead would not clear the barrier. Although step 1 suggested the height of 10.5 ft could be reached by a steelhead, achievement of that height was predicated on jumping straight up in the air (i.e., angle of jump = 90°). Thus, an anadromous-sized steelhead trout (burst speed = 26.5 fps) with a coefficient of fish condition of 1.0 could have jumped either the vertical or the horizontal component of the jump, but could not have jumped both components simultaneously. With respect to barrier B, the answer for step 3 is "no", resulting in the classification of barrier B as a horizontal distance barrier. For barrier B, no more data collection or analysis would be required.

The passage assessment methodology was executed as described below in section 4.2.

4.1.3 Development of an Assessment Methodology for Potential Fish Passage Barriers for Sturgeon

As with the development of a passage methodology for salmonids, any passage methodology developed for sturgeon would need to produce a consistent, repeatable and defensible assessment of fish passage. In order to achieve this goal, the ideal passage methodology would be based on published literature and quantitative fish performance metrics.

However, unlike salmonids, quantitative performance metrics for sturgeon are not currently available in the published literature. Not only are published literature regarding quantitative metrics associated with sturgeon passage metrics not available, there also is very little qualitative published information regarding swimming or leaping performance. The lack of availability of quantitative performance metrics for sturgeon results in no solid foundation from which to base a consistent, repeatable and defensible sturgeon passage assessment. Typical passage assessment methodologies rely upon comparisons of physical metrics of barrier characteristics and fish performance characteristics. Fish performance characteristics utilized in passage assessments typically include burst speed, sustained speed, and leaping curves. Unfortunately, none of these specific fish performance metrics are currently available to quantify sturgeon swimming performance. Dr. Joseph Cech, University of California at Davis, is performing a number of experiments on sturgeon in a swimming flume to quantify sturgeon swimming performance. The results of these experiments may provide information on sturgeon burst and sustained swimming speed, as well as observations of sturgeon use of velocity refuges and substrates preferences, which would be necessary for a quantitative sturgeon passage assessment.

Because detailed passage criteria, such as those developed for salmonids and characterized above, have not been developed for green or white sturgeon, no potential assessment methods met the criteria listed above for a consistent, repeatable and defensible sturgeon passage assessment methodologies. Although the professional opinion of academic and agency sturgeon experts was a potential method with which to assess sturgeon passage at potential migration barriers upstream of Lake Oroville, this method was not deemed to be supportable or desirable. Although academic and agency personnel have extensive expertise in some aspects of sturgeon behavior, habitat, and migrations, few have directed expertise regarding sturgeon swimming performance. This is evidenced by the lack of publications addressing the topic of sturgeon swimming and leaping performance. While professional opinion of sturgeon biologists is currently available, the lack of experimental testing of sturgeon swimming and leaping capability and the lack of numerous or widely documented observations regarding sturgeon passage suggest that even expert assessment would be based on relatively qualitative subjective professional opinion, with relatively few supporting observations for a basis. A previous panel of expert sturgeon biologists assembled to observe potential sturgeon passage barriers in the lower Feather River (SP-F3.2 Task 3A Final Report) illustrated the need for additional scientifically rigorous experiments and observations by concluding that "…*passage determinations at each of the potential passage barriers will continue to be speculative without a greater understanding of sturgeon migration patterns, and physiologic and metabolic limitations*." Additionally, even for the sturgeon biology experts "…*the passage evaluation methods utilized were necessarily either subjective or exploratory due to the lack of quantitative passage information*" (SP-F3.2 Task 3A Final Report). As a result, expert opinion alone was deemed unlikely to provide a defensible and repeatable assessment of potential sturgeon passage barriers upstream of Lake Oroville at this time, given the state of knowledge regarding sturgeon performance metrics.

Fortunately, the physical metrics characterizing potential salmonid passage barriers and the photographs and video footage taken during the salmonid passage barrier assessment could prove useful once additional quantitative data become available regarding sturgeon passage. While the barriers have been characterized physically, the information describing the characteristics cannot be applied to sturgeon until additional research has been conducted to characterize sturgeon swimming and leaping capabilities. As a result, although potential barriers have been physically characterized, a meaningful assessment of the ability of sturgeon to pass them is not possible at this time, and therefore no additional assessment regarding sturgeon passage was conducted.

4.1.4 Evaluation of Frequency of Extreme Hydrologic Conditions

The low flow and high flow passage assessment surveys were conducted at close to the extremes of hydrologic conditions that were available for observation within the year that the study was conducted. In cases where there was evidence that extreme high flows or high reservoir pool conditions might change the passability of a fish barrier, the frequency of these events is presented in the study results to provide a basis for evaluation for how frequent the upstream habitat associated with the fish passage barrier might become accessible (see Figure 5.1-4 and Figure 5.2-4).

4.2 STUDY DESIGN

4.2.1 Pre-survey Site Selection and Assessment Methodology Development

Prior to the field survey conducted to characterize and assess potential fish passage barriers in Lake Oroville's upstream tributaries, two important components contributing to the survey effort were conducted: (1) selection of tributaries to be surveyed; and (2) identification of potential fish passage barriers to be assessed.

4.2.2 Pre-Survey Identification of Potential Fish Passage Impediments

As identified in SP-F3.1, Task 1A, tributaries of Lake Oroville including the 4 major tributaries and tributaries that are 2nd order or larger were to be surveyed for potential fish passage barriers. Potential passage barriers in Lake Oroville's identified upstream tributaries were preliminarily identified using historic records, topographic maps, and the extensive professional knowledge of resource and management agency personnel. A list of potential fish passage barriers for evaluation was constructed for the four major upstream tributaries to Lake Oroville, as well as several relatively small tributary streams as identified in SP-F3.1, Task 1A. For several of the smaller identified tributaries upstream of Lake Oroville, specific named potential migration barriers were not able to be identified using existing resources and therefore no specific potential fish passage barriers were targeted prior to initiation of the field survey. In cases where specific named potential migration barriers were not identified prior to the field survey, the stream was generally surveyed from its confluence with Lake Oroville upstream during the field surveys in an effort to identify specific features that may function as fish passage barriers. A list of the Lake Oroville's upstream tributaries targeted for surveying is presented below, as well as specific potential upstream migration barriers targeted for characterization and assessment when such information was available prior to initiation of the field surveys (Table 4.2-1).

4.3 HOW AND WHERE THE STUDIES WERE CONDUCTED

Known potential passage barriers were accessed by the most efficient means possible, which typically consisted of a combination of initial boat or automobile access, followed by short hikes. Surveys of streams with unknown potential barriers usually started at the interface between the identified stream and either Lake Oroville or its capturing river and continued upstream. Upon recognition of a potential upstream migration barrier, the expert team employed the *Oroville Facilities Relicensing Upstream Migration Barriers Passage Assessment Methodology*, an evaluation technique which utilized a set of hierarchical decision trees and data sheets based upon (with minor application-specific alterations) the analytical methodology and passage criteria developed by Powers and Orsborn (1985). As described in section 4.1.2, the assessment team utilized the barrier-typing decision tree to identify the potential barrier as a fall, chute, boulder cascade, or turbulent cascade. Once the appropriate barrier type was determined, the assessment was then guided by a barrier type-specific passage assessment decision tree, which used a set of measured, estimated or calculated barrier characteristics to evaluate the passage potential of the barrier. Ultimately, the assessment team used the results of the barrier assessment methodology, in conjunction with site-specific supplementary considerations (i.e., potential impediments to the near-optimal passage, leaping, or physical condition elements assumed in the methodology) to agree on a passage determination. During the evaluation of all potential passage barriers, several illustrative photographs and video camera clips also were collected to further document barrier characteristics.

Table 4.2-1. Lake Oroville's upstream tributaries targeted for surveying and specific potential upstream migration barriers targeted for characterization prior to initiation of the field survey.

Upstream Tributary Targeted for Evaluation	Potential Fish Passage Barrier Targeted for Evaluation
Major Tributaries	
West Branch of the North Fork Feather River	Miocene Dam
North Fork Feather River	Big Bend Dam
Middle Fork Feather River	Bald Rock Falls; Curtain Falls
South Fork Feather River	Ponderosa Dam
Minor Tributaries	
Dark Canyon Creek	None identified prior to survey
Concow Creek	None identified prior to survey
Berry Creek	None identified prior to survey
French Creek	None identified prior to survey
Chino Creek	None identified prior to survey
Stony Creek	None identified prior to survey
Sucker Run Creek	None identified prior to survey
Fall River	Feather Falls
Frey Creek	None identified prior to survey
McCabe Creek	None identified prior to survey

The identified tributaries targeted for assessment were evaluated by a passage assessment team of biologists during representative low and high flow conditions, as required by SP-F3.1, Task 1A. The representative low flow passage barrier assessment was conducted over a four-day period from October 28 through 31, 2002, while the representative high flow conditions were evaluated on March 24 and 26, 2003. Due to the logistical complications of visiting a large number of tributaries spread over a large distance and requiring different types of access, several specific tributaries were not visited during these two time periods, but were instead visited in either July 2002 or April 2003. Because of a variety of safety concerns, transportation obstacles, and timing constraints, it was not possible to evaluate each barrier during both flow conditions. For example, several barriers were inaccessible during either high or low flow conditions, or the initial survey of the potential barrier suggested that any further evaluations at other flow conditions would be unmerited. If a tributary was not watered during the low flow observations in late October assessment (during the Chinook spawning season), the fish passage assessment team determined whether the tributary merited evaluation at high flow conditions or not. Furthermore, while quantitative physical measurements at most barriers were successfully completed during the

October 2003 representative low flow evaluations, safety concerns often prevented the expert team from collecting these data during relatively high flows. In cases where the assessment team was prevented from the collection of quantifiable parameters due to safety or timing considerations, the assessment team relied upon a visual estimation of the barrier to estimate the barrier's physical metrics. In these cases, the barrier may have also been judged in relation to barriers of known passage potential. The specific considerations regarding the location and extent of data collection during the October 2002 and March 2003 upstream passage evaluations are described in further detail in section 5.0, Study Results. Every targeted tributary identified was visited during the survey. A description of the flow conditions at which each tributary stream was assessed is presented in Table 4.2-2.

Table 4.2-2. Assessments conducted for tributary streams.

Upstream Tributary and Associated Named Potential Barriers	Assessment Conditions and Dates: Low flow condition (typically from October 28-31, 2002)	Assessment Conditions and Dates: High flow condition (typically from March 24-26, 2003)
West Branch of the North Fork Feather River		
Salmon Falls	Not visited[a]	Visited
Miocene Dam	Visited	Visited
North Fork Feather River		
Big Bend Dam	Visited	Not visited[c]
Middle Fork Feather River		
Bald Rock Falls	Visited	Not visited[b]
Curtain Falls	Visited	Not visited[b]
South Fork Feather River		
Ponderosa Diversion Dam	Visited	Visited
Dark Canyon Creek	Not visited[g]	Visited
Concow Creek	Not visited[d]	Visited[i]
Berry Creek	Visited	Visited
French Creek	Visited	Visited
Chino Creek	Visited	Not visited[b]
Stony Creek	Visited	Not visited[b]
Sucker Run Creek	Visited	Not visited[b]
Fall River	Visited[e]	Not visited[b]
Frey Creek	Visited[e]	Not visited[b]
McCabe Creek	Not visited[h]	Visited[f]

[a]Unaware of barrier's existence at time of assessment;
[b]Safety concerns prohibited visitation of barrier under high flows;
[c]Photo assessment available for high flow condition;
[d]Low reservoir levels prohibited boat access to site;
[e]Assessed July 31, 2002 by Eric See;
[f]Assessed April 22, 2003 by Eric See;
[g]Winter and spring seasonal surface flows only, does not qualify as a 2nd order stream;
[h]Low interest and priority resulted in lack of visitation to this barrier;
[i]Assessed July 29, 2003 by Eric See.

Due to the intensity of the assessment and the associated transportation logistics, members of the passage assessment team varied within and among passage assessment sessions, but the passage assessment team generally consisted of the following individuals:

- Eric See, California Division of Water Resources
- Eric Theiss, NOAA Fisheries
- David White, NOAA Fisheries
- Mike Meinz, California Department of Fish and Game
- Mike Melanson, Metropolitan Water District
- David Olson, SWRI
- Allison Niggemyer, SWRI
- Thomas Duster, SWRI

Upon completion of the assessment at a particular potential passage barrier, the expert team proceeded to the next subsequent barrier, the location of which often depended upon the outcome of the evaluation. For example, if the passage assessment concluded that the barrier was impassable, the assessment team generally ceased their assessment of that stream drainage and traveled to the next identified assessment stream. However, if the potential barrier existed below the full-pool elevation of Lake Oroville (900 feet msl), or the impassability conclusion was met with a degree of speculation, the assessment team usually continued upstream to a barrier of relatively certain characteristics above the full-pool elevation. In some cases, additional upstream investigation was conducted to determine how much habitat might become accessible in the event of potential modification of a barrier to make it passable. In target assessment streams where sufficient knowledge exists regarding potential barriers, only the specific known locations of potential barriers was evaluated, thereby reducing the need for walking/boating surveys of the entire length each of the 14 target streams (see Table 4.2-1). The assessment results are provided below in section 5.0, Study Results.

5.0 STUDY RESULTS

While falls, chutes and cascades were encountered and assessed during the potential passage barrier investigation, the passage assessment team evaluated all potential barriers in accordance with the falls barrier-type methodology. The chutes and cascades observed did not exhibit suitable characteristics to allow a fish to “swim up” their extent. The passage assessment methodology for chutes and cascades is founded on the presumption that fish will be "swimming" up the stream of water instead of "jumping" the distance from the crest of the barrier to the location of the standing wave. If conditions such as excessive water velocity or turbulence make swimming in the water clearly an unlikely possibility and jumping the barrier a likely possibility, it is reasonable to evaluate the barrier as a falls. Because and the most likely passage technique at these potential barriers would entail leaping over the entire structure, the assessment for fall-type barriers was most appropriate for all barriers encountered in this assessment. Therefore, the data and results described herein should be considered in this context.

To the extent possible, the following results are presented using quantitative means, which largely adhere to the format of the assessment methodology. As mentioned in Section 4.2, in some cases the assessment team was prohibited from the collection of quantifiable parameters due to safety or timing considerations, and therefore the assessment team relied upon a visual estimation of the barrier to estimate the barrier's physical metrics. Typically, as discussed above in the section titled "Structure and Use of Data Sheets", a sufficient level of quantitative data was gathered during the field assessment to make a sound decision regarding the passage likelihood at each potential barrier. Because of the sequential structure of the data collection, only the data required to arrive at a decision regarding the likelihood of passage at each barrier were collected. Because the barriers' physical characteristics differ, different data may be required at different barriers; therefore, site-specific data collection varied.

For each potential barrier assessed, results begin with a short description of the location and/or structure of the potential barrier. Assessments made during low and high flow conditions are treated separately. For both the low and high flow assessments, photographs of each potential barrier are provided when available. All data collected in the field under each the flow condition are presented in a table that illustrates the parameters collected, the corresponding data notation utilized in the barrier assessment methodology, the collection methodology (either measured [M] or estimated [E]), and the respective resultant dimensions. In some cases, more data were collected than were required to make a decision regarding barrier passability. This additional data could prove useful in assessing sturgeon passage upon attainment of appropriate metrics, and may be needed to evaluate passability if analytical assumptions are altered or in evaluating a potential PM&E that involves physically altering the barrier structure. When sufficient data was collected at a particular barrier to merit illustration, a table of impediment parameters is provided . With exception of the variation in data collection described above, each table generally conforms to a consistent format, presenting the parameters collected, the corresponding data notation utilized in the barrier assessment methodology, the collection methodology (either measured [M] or estimated [E]), and the respective resultant dimensions. Table 5-1 provides a brief definition for several parameters used regularly within these standard data presentation tables, and throughout the passage evaluation documentation. Additional information regarding the definition of these parameters can be found in Powers and Orsborn (1985).

Table 5-1. Definitions of parameters used to physically characterize potential barriers.

Parameter	Data Notation	Definition
Vertical Barrier Height	H	The change in water surface elevation between the anticipated staging and the landing pools area
Horizontal Width Range	X	The horizontal distance between the anticipated leaping site to the anticipated landing site
Depth of Staging Pool	dpp	The depth of the pool anticipated to serve as the leaping site
Depth of Landing Site	d_c	The depth of the location anticipated to serve as the landing site

While the passage barrier assessment methodology was designed to capture the characteristics of potential passage barriers during representative low and high flows, the actual hydrologic conditions during the assessments did not allow for the documentation of potential extreme conditions. For example, the representative high flow evaluation was conducted during a Lake Oroville pool level of 828 feet msl. Full-pool at Lake Oroville is approximately 901 msl. Therefore, some conjecture will be required to utilize the data presented herein to determine the entire range of possible barrier characteristics and the corresponding passage potential.

5.1 WEST BRANCH OF THE NORTH FORK FEATHER RIVER

5.1.1 Salmon Falls

Description: Salmon Falls are located approximately 2 to 3 miles upstream of the confluence between the West Branch of the North Fork Feather River and Concow Creek at an elevation of approximately 1148 feet, or 250 vertical feet above the full-pool level of Lake Oroville. Salmon Falls is located approximately 3 to 4 miles downstream of Miocene Dam.

Assessment at low flow condition: Salmon Falls was not evaluated by the fish passage assessment team during the October 2002 representative low flow passage assessment. At the time of the October 2002 assessment, the expert team was unaware of its existence.

Assessment at high flow condition: The passage assessment team did, however, evaluate Salmon Falls during the March 2003 representative high flow evaluation. The conditions at Salmon Falls during the evaluation are illustrated in Figures 5.1-1 through 5.1-4 below.

Figure 5.1-1. The deep, steep canyon through which the West Branch of the North Fork Feather River flows and a distant view of Salmon Falls.

Figure 5.1-2. DWR biologist Eric See standing approximately 5 feet in front of the falls, at eye level of the top of the falls, for scale.

Figure 5.1-3. Salmon Falls.

As illustrated in Figure 5.1-2 and Figure 5.1-3, direct measurement of the waterfall was infeasible because of safety concerns. Therefore, the height and horizontal range of the falls were estimated visually. Estimates are presented waterfall parameters are illustrated in Table 5.1-1.

Table 5.1-1. Estimated data characteristics of Salmon Falls collected during the March 2003 passage barrier assessment.

Parameter	Data Notation	Collection Method	Results and Description
Vertical Barrier Height	H	E	15 to 18 feet
Horizontal Width/Range	X	E	60 feet

Using a barrier height measurement of 15 ft, the falls passage assessment was conducted. Step 1 asks: "Is the vertical change in water surface elevation (H) greater than the maximum height of fish's leap (HL) where θL = 90°?" Using the assumptions and variables defined above in section 4.0 and the data sheet for fall-type barriers, each required size and species combination was analyzed.

- **Anadromous-sized Chinook salmon**: The most conservative estimate of the height of Salmon Falls (H) was 15 ft. Using the data sheet for fall-type barriers and the assumptions and variables defined in section 4.0, HL was calculated to be 4.4 ft. Therefore, H>HL and the answer to Step 1 is yes. The analysis suggests that Salmon Falls is an elevation barrier for anadromous-sized Chinook salmon under the high flow conditions observed in March 2003.

- **Anadromous-sized steelhead**: The most conservative estimate of the height of Salmon Falls (H) was 15 ft. Using the data sheet for fall-type barriers and the assumptions and variables defined in section 4.0, HL was calculated to be 6.1 ft. Therefore, H>HL and the answer to Step 1 is yes. The analysis suggests that Salmon Falls is an elevation barrier for anadromous-sized steelhead under the high flow conditions observed in March 2003.

- **Inland-sized Chinook salmon**: The most conservative estimate of the height of Salmon Falls (H) was 15 ft. Using the data sheet for fall-type barriers and the assumptions and variables defined in section 4.0, HL was calculated to be 1.7 ft. Therefore, H>HL and the answer to Step 1 is yes. The analysis suggests that Salmon Falls is an elevation barrier for inland-sized Chinook salmon under the high flow conditions observed in March 2003.

- **Inland-sized coho salmon**: The most conservative estimate of the height of Salmon Falls (H) was 15 ft. Using the data sheet for fall-type barriers and the assumptions and variables defined in section 4.0, HL was calculated to be 1.0 ft. Therefore, H>HL and the answer to Step 1 is yes. The analysis suggests that Salmon Falls is an elevation barrier for inland-sized coho salmon under the high flow conditions observed in March 2003.

The assessment team made several observations during their visit to Salmon Falls. Due to the vertical and horizontal dimensions and turbulent nature of the waterfall, the passage expert assessment team concluded that Salmon Falls represents a significant passage barrier to fish migrating upstream during representative high flow conditions under which the fall was observed. Thus, members of the assessment team deemed Salmon Falls impassable by all four salmonids evaluated under the observed flow conditions.

In addition to the evaluations completed at the observed flow, the assessment team discussed the possibility of passage at flows that were not observed. At lower flows than observed, Salmon Falls would be anticipated to retain its vertical dimensions and therefore would be anticipated to remain impassible as an elevation barrier. The assessment team suggested that the falls would not be expected to become passable during any foreseeable conditions, unless perhaps the falls were to become completely inundated by an extreme high flow event. Overall, Salmon Falls was determined to be likely impassable during most flows for all four salmonids evaluated, recognizing that an absolutely definitive passage barrier assessment would require the reevaluation of Salmon Falls during an extreme range of hydrologic conditions. However, under extreme high flows, passage may be possible.

An evaluation of the frequency of potential fish passage opportunities from high flow events was evaluated for the West Branch of the Feather River. The results of the evaluation will not be definitive of fish passage, but provide some level of insight on the potential frequency in which these events may occur as well as indicate the frequency of potential fish access to upstream habitat (Figure 5.1-4).

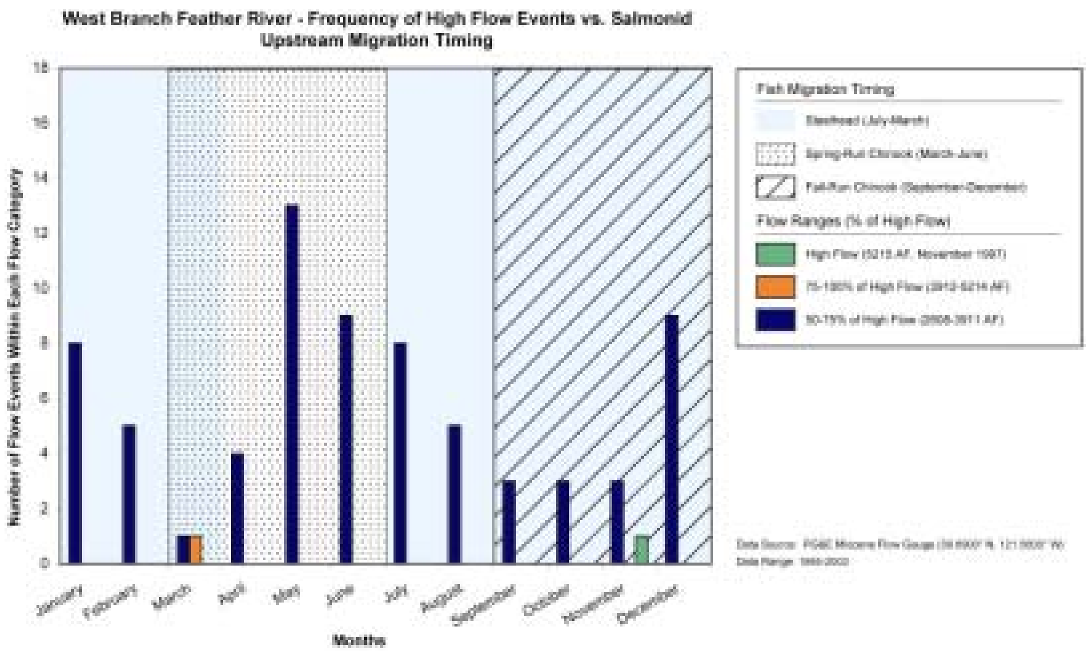


Figure 5.1-4. West Branch Feather River High Flow Event Frequency.

Average monthly flows were used from the PG &E Miocene flow gauge during the 18-year period from 1985 through 2003. High flow events were those calculated to be within at least 50% of the highest recorded flow event, which occurred in November 1997. The frequency of high flow events were calculated based on two categories; flow events between 50 and 75% of the highest recorded flow event, and between 75 and 100% of the highest recorded flow event (5215 AF). The number of high flow events within the flow categories were calculated for each month over the 18-year period. An analysis of the flow event data reveals that out of 216 recorded flow events (flows below 50% of the highest recorded flow were not included in the graph) a majority (99%) of the recorded flows are below 75% of the highest flow event. Upstream migration timing was included in the analysis to compare upstream migration timing of fish species under consideration for passage evaluation, to the frequency of flow events within the flow categories. The comparison of fish migration timing to the frequency of high flow events in the West Branch Feather River reveals that the timing of the highest recorded flow event, which occurred in November 1997, corresponds to the timing of fall run Chinook salmon and steelhead upstream migration periods. Twenty-seven of the high flows corresponding to 50% - 75% of the highest recorded flow out of the 18-year period of record occurred during the spring-run Chinook salmon upstream migration period and 18 occurred during the fall-run Chinook salmon upstream migration period. Actual flow levels required to create conditions that would make impassable fish barriers on the West Branch passable to fish is unknown.

5.1.2 Miocene Dam

Description: Miocene Dam is a concrete diversion dam located approximately 3 to 4 miles upstream of West Branch Falls on the West Branch of the North Fork Feather River. The characteristics of Miocene Dam were directly measured in the field during both representative low and high flow conditions. The results of these evaluations are illustrated in Table 5.1-2.

Assessment at low flow condition: The passage assessment team evaluated Miocene Dam during the October 2002 representative low flow evaluation. The conditions at Miocene Dam during the evaluation are illustrated in Figures 5.1-5 and Figure 5.1-6.

The characteristics of Miocene Dam were directly measured in the field during the representative low flow condition. Measured data are presented in Table 5.1-2.

Table 5.1-2. Measured data characteristics of Miocene Dam collected during the October 2002 passage barrier assessments.

Parameter	Data Notation	Collection Method	Results and Description
Vertical Barrier Height	H	M	10.1 feet
Horizontal Width Range	X	M	Minimum of 2.5 feet; Maximum of 10.5 feet near the majority of the attraction flow
Depth of Staging Pool	dpp	M	15 feet
Depth of Landing Site	d_c	M	1.2 feet

Figure 5.1-5. Looking upstream at Miocene Dam while Dave Olson, Thomas Duster, and Eric Theiss discuss the structure.

Figure 5.1-6. Far river-left portion of Miocene Dam.

Using a barrier height measurement of 10.1 ft, the falls passage assessment was conducted. Step 1 asks: "Is the vertical change in water surface elevation (H) greater than the maximum height of fish's leap (HL) where $\theta L = 90°$?" Using the assumptions and variables defined above in section 4.0, Methodology and the data sheet for fall-type barriers, each required size and species combination was analyzed.

- **Anadromous-sized Chinook salmon**: The measured height of Miocene Dam (H) was 10.1 ft. Using the data sheet for fall-type barriers and the assumptions and variables defined in section 4.0, HL was calculated to be 4.4 ft. Therefore, H>HL and the answer to Step 1 is yes. The analysis suggests that Miocene Dam is an elevation barrier for anadromous-sized Chinook salmon under the low flow conditions observed in October 2002.

- **Anadromous-sized steelhead**: The measured height of Miocene Dam (H) was 10.1 ft. Using the data sheet for fall-type barriers and the assumptions and variables defined in section 4.0, HL was calculated to be 6.1 ft. Therefore, H>HL and the answer to Step 1 is yes. The analysis suggests that Miocene Dam is an elevation barrier for anadromous-sized steelhead under the low flow conditions observed in October 2002.

- **Inland-sized Chinook salmon**: The measured height of Miocene Dam (H) was 10.1 ft. Using the data sheet for fall-type barriers and the assumptions and variables defined in section 4.0, HL was calculated to be 1.7 ft. Therefore, H>HL and the answer to Step 1 is yes. The analysis suggests that Miocene Dam is an elevation barrier for inland-sized Chinook salmon under the low flow conditions observed in October 2002.

- **Inland-sized coho salmon**: The measured height of Miocene Dam (H) was 10.1 ft. Using the data sheet for fall-type barriers and the assumptions and variables defined in section 4.0, HL was calculated to be 1.0 ft. Therefore, H>HL and the answer to Step 1 is yes. The analysis suggests that Miocene Dam is an elevation barrier for inland-sized coho salmon under the low flow conditions observed in October 2002.

The assessment team made several observations during their October 2002 visit to Miocene Dam. The assessment team reached general consensus regarding the impassibility of Miocene Dam under the observed flow conditions. The passage methodology illustrated that the barrier height (and further, the horizontal range) would not allow a salmonid of the appropriate condition factor to pass the dam, particularly when considering the barrier width near the majority of the attraction flow. Thus, members of the assessment team deemed Miocene Dam impassable by all four salmonids evaluated under the observed low flow conditions.

During the October 2002 evaluation, the fish passage assessment team reached general consensus regarding the impassibility of Miocene Dam under the observed flow conditions. The passage methodology illustrated that the combination of the barrier height and width would not allow a salmonid of the appropriate condition factor to pass the dam, particularly when considering the barrier width near the majority of the attraction flow.

Assessment at high flow condition: The passage assessment team evaluated Miocene Dam during the March 2003 representative high flow evaluation. The conditions at Miocene Dam during the evaluation are illustrated in Figure 5.1-7.

Figure 5.1-7. Miocene Dam in March 2003.

The characteristics of Miocene Dam were directly measured in the field during the representative high flow condition. Measured data are presented in Table 5.1-3.

Table 5.1-3. Measured data characteristics of Miocene Dam collected during the March 2003 passage barrier assessments.

Parameter	Data Notation	Collection Method	Results and Description
Barrier Height	H	M	7.9 feet
Horizontal Range	X	M	7.5 feet
Depth of Landing Site	d_c	M	1.2 feet

Using a barrier height measurement of 7.9 ft, the falls passage assessment was conducted. Step 1 asks: "Is the vertical change in water surface elevation (H) greater than the maximum height of fish's leap (HL) where $\theta L = 90°$?" Using the assumptions and variables defined above in section 4.0, and the data sheet for fall-type barriers, each required size and species combination was analyzed.

- **Anadromous-sized Chinook salmon**: The measured height of Miocene Dam (H) was 7.9 ft. Using the data sheet for fall-type barriers and the assumptions and variables defined in section 4.0, HL was calculated to be 4.4 ft. Therefore, H>HL and the answer to Step 1 is yes. The analysis suggests that Miocene Dam is an elevation barrier for anadromous-sized Chinook salmon under the high flow conditions observed in March 2003.

- **Anadromous-sized steelhead**: The measured height of Miocene Dam (H) is 7.9 ft. Using the data sheet for fall-type barriers and the assumptions and variables defined in section 4.0, HL was calculated to be 6.1 ft. Therefore, H>HL and the answer to Step 1 is yes. The analysis suggests that Miocene Dam is an elevation barrier for anadromous-sized steelhead under the high flow conditions observed in March 2003.

- **Inland-sized Chinook salmon**: The measured height of Miocene Dam (H) is 7.9 ft. Using the data sheet for fall-type barriers and the assumptions and variables defined in section 4.0, HL was calculated to be 1.7 ft. Therefore, H>HL and the answer to Step 1 is yes. The analysis suggests that Miocene Dam is an elevation barrier for inland-sized Chinook salmon under the high flow conditions observed in March 2003.

- **Inland-sized coho salmon**: The measured height of Miocene Dam (H) is 7.9 ft. Using the data sheet for fall-type barriers and the assumptions and variables defined in section 4.0, HL was calculated to be 1.0 ft. Therefore, H>HL and the answer to Step 1 is yes. The analysis suggests that Miocene Dam is an elevation barrier for inland-sized coho salmon under the high flow conditions observed in March 2003.

The assessment team made several observations during their March 2003 visit to Miocene Dam. In addition to the physical measurements described in Table 5.1-3, several other significant factors were considered when evaluating Miocene Dam during the March 2003 assessment. The staging pool at Miocene Dam was very turbulent under the relatively high flow conditions, and appeared to be saturated with entrained air, diminishing the jumping capacity of an adult salmonid. The sill of the dam exhibited nearly optimal landing conditions, as the flow was essentially uniform, with limited entrained air or turbulence. However, during the observed representative high flow conditions, the passage evaluation appears to conclude that Miocene Dam would be impassable to an upmigrating adult salmonid due to the combination between the barrier height and width. Thus, members of the assessment team deemed Miocene Dam impassable by all four salmonids evaluated under the observed high flow conditions.

In addition to the evaluations completed at the observed flows, the assessment team discussed the possibility of passage at flows that were not observed. The assessment team suggested that immediately downstream of Miocene Dam, there is evidence of the historic high water mark which suggests that under past flow conditions, Miocene Dam may become completely inundated. During these extremely high flow events fish passage may become possible (see Figure 5.1-4). However, determination of the specific conditions in at which there would be sufficient flow to inundate Miocene Dam and therefore increase the likelihood of passage would require further field investigations and validation. The increase in flow required to inundate Miocene Dam may result in water velocities that would prohibit salmonid passage. Overall, Miocene Dam was determined to be likely impassable for all four salmonids evaluated, recognizing that an absolutely definitive passage barrier assessment would require the reevaluation of Miocene Dam during an extreme range of hydrologic conditions.

5.2 NORTH FORK FEATHER RIVER

5.2.1 Big Bend Dam

Description: Big Bend Dam is a concrete dam located on the North Fork Feather River, approximately 0.5 miles downstream of Poe Powerhouse. The dam crosses the entire river channel and passes water directly over its top during high flow conditions. During relatively low flow conditions, water passes Big Bend Dam through a notch cut out of the middle of its span (Figure 5.2-1).

Figure 5.2-1. Oblique aerial photograph of Big Bend Dam –looking upstream – June 2002.

The expert team evaluated Big Bend Dam only during the October 2002 representative low flow conditions. Table 5.2-1 illustrates the measured parameters obtained during the assessment.

Assessment at low flow condition: The passage assessment team evaluated Big Bend Dam during the October 2002 representative high flow evaluation. The conditions at Big Bend Dam during the evaluation are illustrated in Figure 5.2-2.

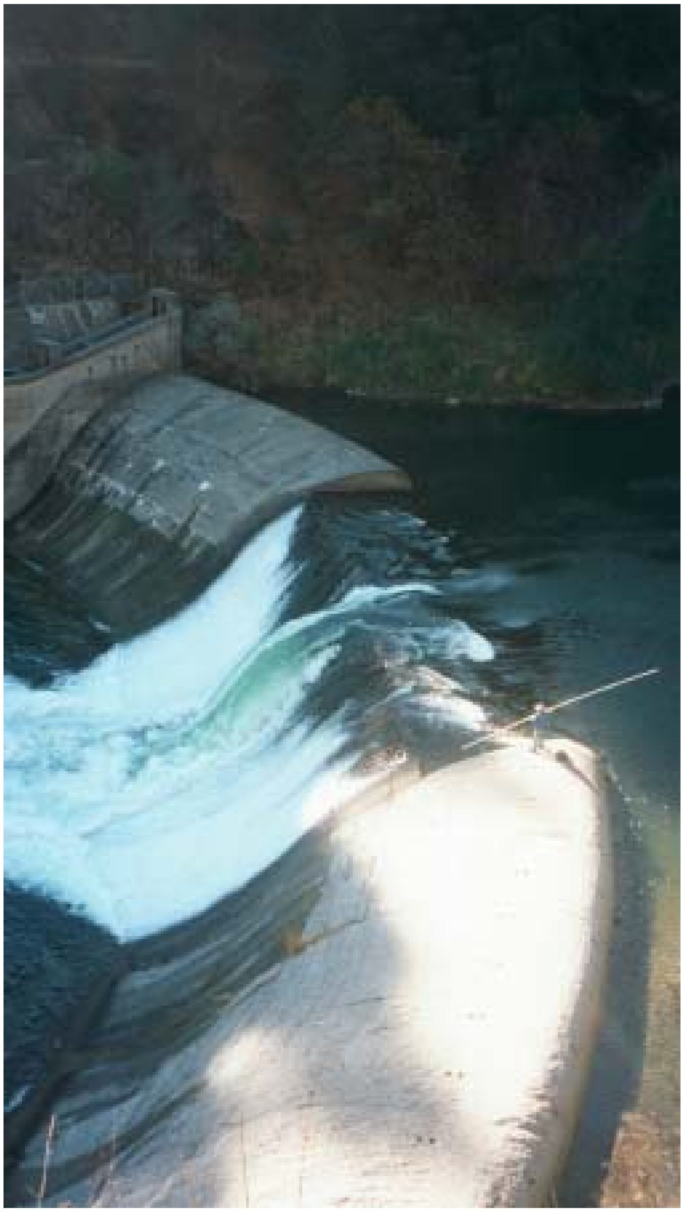


Figure 5.2-2. Overhead view of Big Bend Dam with DWR biologist Eric See holding a 25 foot stadia rod horizontally across the upstream-downstream length of Big Bend Dam.

The characteristics of Big Bend Dam were directly measured in the field during the representative low flow condition. Measured data are presented in Table 5.2-1.

Table 5.2-1. Measured data characteristics of Big Bend Dam collected during the October 2002 passage barrier assessment.

Parameter	Data Notation	Collection Method	Results and Description
Vertical Barrier Height	H	M	36 feet in total height; 30 feet to the notch where a majority of the flow exist
Depth of Landing Site	d_c	M	1.5 to 2 feet on the edge of the notch; unknown depth in the middle of the notch

Using a barrier height measurement of 30 ft, the falls passage assessment was conducted. Step 1 asks: "Is the vertical change in water surface elevation (H) greater than the maximum height of fish's leap (HL) where $\theta L = 90°$?" Using the assumptions and variables defined above in section 4.0, and the data sheet for fall-type barriers, each required size and species combination was analyzed.

- **Anadromous-sized Chinook salmon**: The most conservative measured height of Big Bend Dam (H) was 30 ft. Using the data sheet for fall-type barriers and the assumptions and variables defined in section 4.0, HL was calculated to be 4.4 ft. Therefore, H>HL and the answer to Step 1 is yes. The analysis suggests that Big Bend Dam is an elevation barrier for anadromous-sized Chinook salmon under the low flow conditions observed in October 2002.

- **Anadromous-sized steelhead**: The most conservative measured height of Big Bend Dam (H) was 30 ft. Using the data sheet for fall-type barriers and the assumptions and variables defined in section 4.0, HL was calculated to be 6.1 ft. Therefore, H>HL and the answer to Step 1 is yes. The analysis suggests that Big Bend Dam is an elevation barrier for anadromous-sized steelhead under the low flow conditions observed in October 2002.

- **Inland-sized Chinook salmon**: The most conservative measured height of Big Bend Dam (H) was 30 ft. Using the data sheet for fall-type barriers and the assumptions and variables defined in section 4.0, HL was calculated to be 1.7 ft. Therefore, H>HL and the answer to Step 1 is yes. The analysis suggests that Big Bend Dam is an elevation barrier for inland-sized Chinook salmon under the low flow conditions observed in October 2002.

- **Inland-sized coho salmon**: The most conservative measured height of Big Bend Dam (H) was 30 ft. Using the data sheet for fall-type barriers and the assumptions and variables defined in section 4.0, HL was calculated to be 1.0 ft. Therefore, H>HL and the answer to Step 1 is yes. The analysis suggests that Big Bend Dam is an elevation barrier for inland-sized coho salmon under the low flow conditions observed in October 2002.

The assessment team made several observations during their October 2002 visit to Big Bend Dam. While safety considerations inhibited the passage team from measuring the depth of the staging pool, it is likely very deep and not a limiting factor in passage at the dam. In addition, water passing the dam and entering the staging pool created significant turbulence, which saturated the pool with entrained air. Due to its vertical height and the relatively large water velocity of water leaving the notch, Big Bend Dam is a likely significant passage barrier for upmigrating adult salmonids. Thus, members of the assessment team deemed Big Bend Dam impassable by all four salmonids evaluated under the observed low flow condition.

Assessment at high flow condition: The passage assessment team did not evaluate Big Bend Dam during the March 2003 representative high flow evaluation. Photographs illustrating the conditions at Big Bend Dam during reservoir high pool conditions in the spring of 2003 were taken by DWR Geomorphologist Bruce Ross. The conditions at Big Bend Dam in spring 2003 are illustrated in Figure 5.2-3.

Figure 5.2-3. Big Bend Dam during Oroville reservoir high pool conditions (photo: Bruce Ross, DWR).

The characteristics of Big Bend Dam were not measured in the field during the representative high flow condition. However, the photograph indicates that under the high flow condition observed, no barrier is present. Regarding the conditions at Big Bend Dam, DWR Geomorphologist Bruce Ross observed, "a person could swim it".

Clearly, at reservoir high pool conditions such as those represented here, Big Bend Dam would not be expected to constitute a barrier for any of the four salmonids evaluated under the observed conditions.

Because Big Bend Dam was not evaluated during the March 2003 passage assessment, its characteristics during representative high flows remain unknown. The combined results of the low flow condition passage assessment and the photograph available representing Big Bend Dam at a reservoir high pool condition suggest that the barrier status of Big Bend Dam is variable depending upon the reservoir stage elevation. For all four salmonids evaluated, Big Bend Dam was impassible under the low flow condition observed in October 2002 and was passable under the reservoir high pool condition observed in spring 2003. In addition, it is possible that a sufficient flow to either inundate the dam completely or raise the staging pool to a level within leaping reach of an adult salmonid may provide a passage opportunity for upmigrating fish. However, the flow levels sufficient to create these conditions at Big Bend Dam cannot be accurately estimated. Extreme flows may result in water velocities that prohibit salmonid passage, and thus specific field investigations under this condition would be required to evaluate passability at extremely high flows. Overall, Big Bend Dam was determined to be impassable by all four salmonids evaluated under low flow conditions and passable under reservoir high pool conditions.

Based on field observations of the DWR Geomorphologists and the photograph in Figure 5.2-3, it was assumed that high pool events would accommodate fish passage. In order to evaluate the frequency in which fish would be able to pass Big Bend Dam and access upstream habitat, the monthly surface water elevations for Lake Oroville during the period of 1967-2001 were evaluated to determine the frequency of high pool events. The number of high pool events within 5 and 10 feet of the reservoir high pool elevation of 900' were calculated for each month. The high pool event timing were compared to the upstream migration timing of the fish under consideration for passage to determine if the passage opportunities occurred at times of year and frequency of occurrence that would contribute to functional accessibility for fish passage to the upstream reaches. The comparison of the timing of the high pool events to the upstream migration timing indicates that the only significant overlap in timing is with spring-run Chinook salmon, for which 25 out of 26 high pool events recorded over the 34 year period fell within their migration timing range. Steelhead migration timing has significantly less overlap relative to spring-run Chinook salmon, and corresponds to only 1-recorded high pool event over the entire 34-year period. In the case of fall-run Chinook salmon, migration timing does not overlap with any of the recorded high pool events. The results of our analysis indicate that passage of steelhead and fall-run Chinook salmon may not be possible if the timing of high pool events recorded from 1967-2001 are indicative of future conditions.

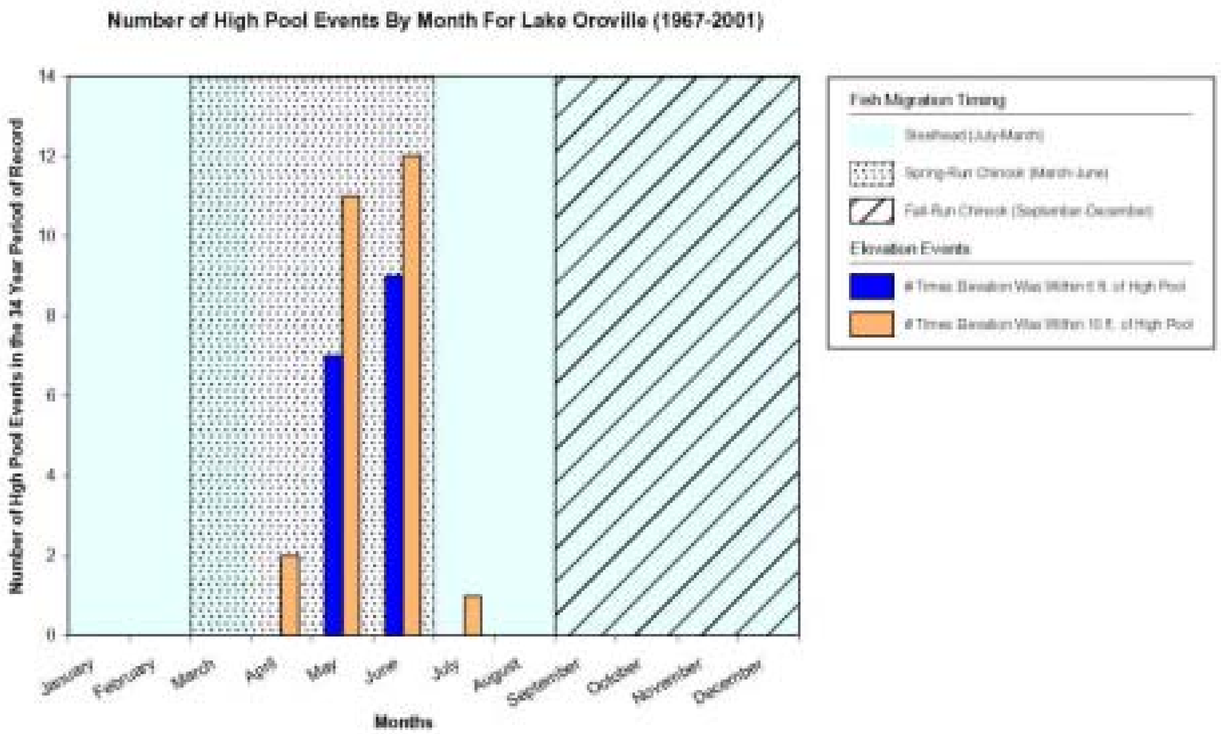


Figure 5.2-4. Oroville reservoir high pool frequency vs. salmonid upstream migration timing.

5.3 MIDDLE FORK FEATHER RIVER

5.3.1 Bald Rock Falls and Curtain Falls

Description: Bald Rock Falls and Curtain Falls are located on the Middle Fork Feather River, approximately 1 to 2 miles upstream of its confluence with the Fall River, and within Bald Rock Canyon. Bald Rock Falls is approximately 300 to 400 yards downstream of Curtain Falls.

Assessment at low flow condition: The expert passage assessment team visually assessed Bald Rock Falls and collected physical data at Curtain Falls during the October 2002 representative low flow conditions. Although photographs are not available of Bald Rock Falls and Curtain Falls, video footage of Curtain Falls is available. The characteristics of Curtain Falls were measured in the field during the representative low flow condition. Measured data are presented in Table 5.3-1.

Table 5.3-1. Measured data characteristics of Curtain Falls collected during the October 2002 passage barrier assessment.

Parameter	Data Notation	Collection Method	Results and Description
Barrier Height	H	M	approximately 25 feet
Horizontal Range	X	M	19 feet
Depth of Staging Pool	dpp	E	> 10 feet

Using a barrier height measurement of 25 ft, the falls passage assessment was conducted. Step 1 asks: "Is the vertical change in water surface elevation (H) greater than the maximum height of fish's leap (HL) where $\theta L = 90°$?" Using the assumptions and variables defined above in section 4.0, and the data sheet for fall-type barriers, each required size and species combination was analyzed.

- **Anadromous-sized Chinook salmon**: The measured height of Curtain Falls (H) was 25 ft. Using the data sheet for fall-type barriers and the assumptions and variables defined in section 4.0, HL was calculated to be 4.4 ft. Therefore, H>HL and the answer to Step 1 is yes. The analysis suggests that Curtain Falls is an elevation barrier for anadromous-sized Chinook salmon under the low flow conditions observed in October 2002.

- **Anadromous-sized steelhead**: The measured height of Curtain Falls (H) was 25 ft. Using the data sheet for fall-type barriers and the assumptions and variables defined in section 4.0, HL was calculated to be 6.1 ft. Therefore, H>HL and the answer to Step 1 is yes. The analysis suggests that Curtain Falls is an elevation barrier for anadromous-sized steelhead under the low flow conditions observed in October 2002.

- **Inland-sized Chinook salmon**: The measured height of Curtain Falls (H) was 25 ft. Using the data sheet for fall-type barriers and the assumptions and variables defined in section 4.0, HL was calculated to be 1.7 ft. Therefore, H>HL and the answer to Step 1 is yes. The analysis suggests that Curtain Falls is an elevation barrier for inland-sized Chinook salmon under the low flow conditions observed in October 2002.

- **Inland-sized coho salmon**: The measured height of Curtain Falls (H) was 25 ft. Using the data sheet for fall-type barriers and the assumptions and variables defined in section 4.0, HL was calculated to be 1.0 ft. Therefore, H>HL and the answer to Step 1 is yes. The analysis suggests that Curtain Falls is an elevation barrier for inland-sized coho salmon under the low flow conditions observed in October 2002.

The assessment team made several observations during their October 2002 visit to Bald Rock Falls and Curtain Falls. While Bald Rock Falls appeared to be slightly smaller than Curtain Falls, the assessment team observed that both falls represent significant upstream migration barriers. Although the assessment team did not measure the chute just downstream of the pool at the base of Curtain Falls, they noted that it appeared to be a barrier as well, dropping approximately 15 ft vertically and about 50 ft. horizontally. Water depth was approximately one to two inches, as can be seen in the video footage. The chute that precedes the lip of the Curtain Falls consisted of a vertical drop of 7.2 ft and a horizontal run of 43 ft. Because of the height of Bald Rock

Falls and Curtain Falls, members of the assessment team deemed Bald Rock Falls and Curtain Falls impassable by all four salmonids evaluated under the observed low flow conditions.

Assessment at high flow condition: Due to significant safety and travel considerations, the falls were not reevaluated during relatively high flows. While Bald Rock Falls appeared to be slightly smaller than Curtain Falls, both falls represent significant upstream migration barriers.

In addition to the evaluations completed at the observed flow, the assessment team discussed the possibility of passage at flows that were not observed. The assessment team observed that due to the limited floodplain, steep canyon walls, and potential for significant flows on the Middle Fork Feather River, Bald Rock and Curtain Falls likely exhibit vastly different characteristics during high flow events. An increase in flow may result in changing falls to chutes and may result in increased water velocities, turbulence and entrainment of air; however, because analytical tools are currently not available to evaluate how Bald Rock Falls and Curtain Falls would be altered under increased flows, specific field investigations at high flow conditions would be required to evaluate passability at under high flows. Thus, the likelihood of passage at these features Bald Rock Falls and Curtain Falls during relatively high flow conditions remains unknown. However, the expert passage assessment team determined that both falls were likely passage barriers at relatively high flows. Overall, Bald Rock Falls and Curtain Falls were determined to be impassable by all four salmonids evaluated at low flow conditions and unknown, although likely impassable, at high flow conditions, recognizing that an absolutely definitive passage barrier assessment would require the reevaluation of Bald Rock Falls and Curtain Falls during an extreme range of hydrologic conditions.

5.4 SOUTH FORK FEATHER RIVER

5.4.1 Ponderosa Diversion Dam

Description: Ponderosa Dam is a large earth-fill dam on the South Fork Feather River near the full-pool level of Lake Oroville. The dam has a concrete spillway on river-right which serves as a very straight, high velocity chute ending with a waterfall.

Assessment at low flow condition: The passage assessment team evaluated Ponderosa Diversion Dam during the October 2002 representative low flow evaluation. The conditions at Ponderosa Dam during the evaluation are illustrated in Figures 5.4-1 through 5.4-2.

Figure 5.4-1. Ponderosa Dam spillway as it flows into the South Fork Feather River.

Figure 5.4-2. Waterfall at end of Ponderosa Dam spillway looking downstream on the South Fork Feather River.

The characteristics of Ponderosa Dam were estimated in the field during the representative low flow condition. Estimated data are presented in Table 5.4-1.

Table 5.4-1. Estimated data characteristics of Ponderosa Dam collected during the October 2002 passage barrier assessments.

Parameter	Data Notation	Collection Method	Results and Description
Barrier Height	H	E	35 to 45 feet

Using a barrier height measurement of 35 ft, the falls passage assessment was conducted. Step 1 asks: "Is the vertical change in water surface elevation (H) greater than the maximum height of fish's leap (HL) where $\theta L = 90°$?" Using the assumptions and variables defined above in section 4.0, and the data sheet for fall-type barriers, each required size and species combination was analyzed.

- **Anadromous-sized Chinook salmon**: The most conservative estimated height of Ponderosa Dam (H) was 35 ft. Using the data sheet for fall-type barriers and the assumptions and variables defined in section 4.0, HL was calculated to be 4.4 ft. Therefore, H>HL and the answer to Step 1 is yes. The analysis suggests that Ponderosa Dam is an elevation barrier for anadromous-sized Chinook salmon under the low flow conditions observed in October 2002.

- **Anadromous-sized steelhead**: The most conservative estimated height of Ponderosa Dam (H) was 35 ft. Using the data sheet for fall-type barriers and the assumptions and variables defined in section 4.0 Methodology, HL was calculated to be 6.1 ft. Therefore, H>HL and the answer to Step 1 is yes. The analysis suggests that Ponderosa Dam is an elevation barrier for anadromous-sized steelhead under the low flow conditions observed in October 2002.

- **Inland-sized Chinook salmon**: The most conservative estimated height of Ponderosa Dam (H) was 10.1 ft. Using the data sheet for fall-type barriers and the assumptions and variables defined in section 4.0, HL was calculated to be 1.7 ft. Therefore, H>HL and the answer to Step 1 is yes. The analysis suggests that Ponderosa Dam is an elevation barrier for inland-sized Chinook salmon under the low flow conditions observed in October 2002.

- **Inland-sized coho salmon**: The most conservative estimated height of Ponderosa Dam (H) was 10.1 ft. Using the data sheet for fall-type barriers and the assumptions and variables defined in section 4.0, HL was calculated to be 1.0 ft. Therefore, H>HL and the answer to Step 1 is yes. The analysis suggests that Ponderosa Dam is an elevation barrier for inland-sized coho salmon under the low flow conditions observed in October 2002.

The assessment team generally agreed that the waterfall at the end of the Ponderosa Dam spillway was completely impassable to adult salmonids during the observed low flow conditions during October 2002.

Assessment at high flow condition: The passage assessment team evaluated Ponderosa Dam during the March 2003 representative high flow evaluation. The conditions at Ponderosa Dam during the evaluation are illustrated in Figure 5.4-3.

Figure 5.4-3. Ponderosa Dam in March 2003.

The characteristics of Ponderosa Dam were estimated in the field during the representative low flow condition. Estimated data are presented in Table 5.4-2.

Table 5.4-2. Estimated data characteristics of Ponderosa Dam collected during the October 2002 passage barrier assessments.

Parameter	Data Notation	Collection Method	Results and Description
Barrier Height	H	E	35 to 45 feet

Using a barrier height measurement of 35 ft, the falls passage assessment was conducted. Step 1 asks: "Is the vertical change in water surface elevation (H) greater than the maximum height of fish's leap (HL) where $\theta L = 90°$?" Using the assumptions and variables defined above in section 4.0, and the data sheet for fall-type barriers, each required size and species combination was analyzed.

- **Anadromous-sized Chinook salmon**: The most conservative estimated height of Ponderosa Dam (H) was 35 ft. Using the data sheet for fall-type barriers and the assumptions and variables defined in section 4.0, HL was calculated to be 4.4 ft. Therefore, H>HL and the answer to Step 1 is yes. The analysis suggests that Ponderosa Dam is an elevation barrier for anadromous-sized Chinook salmon under the high flow conditions observed in March 2003.

- **Anadromous-sized steelhead**: The most conservative estimated height of Ponderosa Dam (H) was 35 ft. Using the data sheet for fall-type barriers and the assumptions and variables defined in section 4.0, HL was calculated to be 6.1 ft. Therefore, H>HL and the answer to Step 1 is yes. The analysis suggests that Ponderosa Dam is an elevation barrier for anadromous-sized steelhead under the high flow conditions observed in March 2003.

- **Inland-sized Chinook salmon**: The most conservative estimated height of Ponderosa Dam (H) was 10.1 ft. Using the data sheet for fall-type barriers and the assumptions and variables defined in section 4.0, HL was calculated to be 1.7 ft. Therefore, H>HL and the answer to Step 1 is yes. The analysis suggests that Ponderosa Dam is an elevation barrier for inland-sized Chinook salmon under the high flow conditions observed in March 2003.

- **Inland-sized coho salmon**: The most conservative estimated height of Ponderosa Dam (H) was 10.1 ft. Using the data sheet for fall-type barriers and the assumptions and variables defined in section 4.0, HL was calculated to be 1.0 ft. Therefore, H>HL and the answer to Step 1 is yes. The analysis suggests that Ponderosa Dam is an elevation barrier for inland-sized coho salmon under the high flow conditions observed in March 2003.

Because the spillway contained no flow at all during the October 2002 evaluation, the hydrologic conditions at Ponderosa Dam were fairly similar between the representative high and low flow assessments. As in the low flow assessment, the assessment team generally agreed that Ponderosa Dam was completely impassable to adult salmonids during the observed flow conditions.

In addition to the evaluations completed at the observed flows, the assessment team discussed the possibility of passage at flows that were not observed. The assessment team agreed that at the two observed flows, Ponderosa Dam was impassible for all evaluated immigrating adult salmonids. However, under full pool conditions in Lake Oroville, the falls at the end of the spillway may become substantially smaller or completely inundated. Therefore, careful evaluations of the likelihood of passage at the spillway chute may be merited during a typical spill condition when Lake Oroville is at full pool. However, the assessment team speculated that due to the length of the spillway chute, the expected substantial water velocities, and the expected shallow depth of the spill water, fish passage during a representative spill condition would be unlikely. Overall, Ponderosa Dam was determined to be impassable by all four salmonids evaluated under low flow and under high flow conditions and was anticipated to be impassible even when Lake Oroville was at full pool, recognizing that an absolutely definitive passage barrier assessment would require the reevaluation of Ponderosa Dam during a larger range of hydrologic conditions, including very extreme conditions.

5.5 SMALL TRIBUTARIES

5.5.1 Dark Canyon Creek

Description: Dark Canyon Creek is a small upstream tributary which flows directly into Lake Oroville between the arms of the West Branch of the North Fork Feather River and the North Fork Feather River.

Assessment at low flow condition: The passage assessment team did not evaluate Dark Canyon Creek during the October 2002 representative low flow evaluation. Based on the relatively low flows observed during the high flow assessment, it is likely that at low flows all of the flow in Dark Canyon Creek would be subsurface and therefore impassable to fish.

Assessment at high flow condition: The passage assessment team visited Dark Canyon Creek during the March 2003 representative high flow evaluation. The conditions at Dark Canyon Creek during the evaluation are illustrated in Figure 5.5-1.

Figure 5.5-1. Looking upstream into Dark Canyon from the interface of Dark Canyon Creek with Lake Oroville.

During the March 2003 passage evaluation, the expert assessment team briefly observed Dark Canyon Creek near its interface with Lake Oroville. The passage assessment expert team did not investigate the Dark Canyon drainage for the presence of potential migration barriers because the stream contained very little flow and a significant amount of sediment had been deposited in the stream channel. As a result, the assessment team generally agreed that Dark Canyon Creek did not merit further evaluation as it appears unsuitable for salmonids due to the deposition of vast amounts of sediment.

5.5.2 Concow Creek

Description: Concow Creek is a tributary of the West Branch of the North Fork Feather River. The creek is characterized by large bedrock pools separated by cascades.

Assessment at low flow condition: The passage assessment team did not evaluate Concow Creek during the October 2002 representative low flow evaluation, because boat access to the stream was restricted by low-reservoir conditions. However, a potential barrier, Middle/Upper Concow Creek Falls located approximately 250 m upstream of the high water mark of Lake Oroville, was evaluated on July 29, 2003. The conditions at Middle/Upper Concow Creek Falls are illustrated in Figure 5.5-2.

Figure 5.5-2. Middle/Upper Concow Creek Falls on July 29, 2003. Middle Concow Creek Falls is the lower of the two falls and Upper Concow Creek Falls is the upper of the two falls pictured here.

The characteristics of Middle/Upper Concow Creek Falls were directly measured in the field by Eric See during the representative low flow condition on July 29, 2003. Measured data are presented in Table 5.5-1.

Table 5.5-1. Measured data characteristics of Middle/Upper Concow Creek Falls collected on July 29, 2003.

Parameter	Data Notation	Collection Method	Results and Description
Barrier Height	H	M	Middle Falls: 8 feet Upper Falls: 13 feet
Horizontal Range	X	M	Middle Falls: 3 feet Upper Falls: 3 feet
Depth of Staging Pool	dpp	M	Middle Falls: no staging pool Upper Falls: ~ 5 feet

Using barrier height measurements of 8 ft and 13 ft, the falls passage assessment was conducted. Step 1 asks: "Is the vertical change in water surface elevation (H) greater than the maximum height of fish's leap (HL) where θL = 90°?" Using the assumptions and variables defined above in section 4.0, and the data sheet for fall-type barriers, each required size and species combination was analyzed.

- **Anadromous-sized Chinook salmon**: The measured heights of Middle Concow Creek Falls and Upper Concow Creek Falls (H) were 8 ft and 13 ft, respectively. Using the data sheet for fall-type barriers and the assumptions and variables defined in section 4.0, HL was calculated to be 4.4 ft. Therefore, H>HL and the answer to Step 1 is yes. The analysis suggests that both Middle Concow Creek Falls and Upper Concow Creek Falls are elevation barriers for anadromous-sized Chinook salmon under the low flow conditions observed in July 2003.

- **Anadromous-sized steelhead**: The measured heights of Middle Concow Creek Falls and Upper Concow Creek Falls (H) were 8 ft and 13 ft, respectively. Using the data sheet for fall-type barriers and the assumptions and variables defined in section 4.0, HL was calculated to be 6.1 ft. Therefore, H>HL and the answer to Step 1 is yes. The analysis suggests that both Middle Concow Creek Falls and Upper Concow Creek Falls are elevation barriers for anadromous-sized steelhead under the low flow conditions observed in July 2003.

- **Inland-sized Chinook salmon**: The measured heights of Middle Concow Creek Falls and Upper Concow Creek Falls (H) were 8 ft and 13 ft, respectively. Using the data sheet for fall-type barriers and the assumptions and variables defined in section 4.0, HL was calculated to be 1.7 ft. Therefore, H>HL and the answer to Step 1 is yes. The analysis suggests that both Middle Concow Creek Falls and Upper Concow Creek Falls are elevation barriers for inland-sized Chinook salmon under the low flow conditions observed in July 2003.

- **Inland-sized coho salmon**: The measured heights of Middle Concow Creek Falls and Upper Concow Creek Falls (H) were 8 ft and 13 ft, respectively. Using the data sheet for fall-type barriers and the assumptions and variables defined in section 4.0, HL was calculated to be 1.0 ft. Therefore, H>HL and the answer to Step 1 is yes. The analysis suggests that both Middle Concow Creek Falls and Upper Concow Creek Falls are elevation barriers for inland-sized coho salmon under the low flow conditions observed in July 2003.

The analysis suggests that both Middle and Upper Concow Creek Falls is impassable by all four salmonids evaluated under the observed low flow conditions.

Assessment at high flow condition: The passage assessment team visited Concow Creek during the March 2003 representative high flow evaluation. Concow Creek Falls is situated at the full-pool level of Lake Oroville. The conditions at Concow Creek Falls during the evaluation are illustrated in Figure 5.5-3.

Figure 5.5-3. Concow Creek Falls in March 2003.

The expert team did, however, assess the stream during the March 2003 passage barrier assessment. During the representative high flow evaluation in March 2003, three several potential passage barriers were identified within the first one mile section of Concow Creek. The first several potential barriers were photographed, but because they were within the full-pool level of Lake Oroville and preliminarily appeared to be passable, the passage expert team omitted quantitative evaluation of these two barriers in order to survey further upstream. The third potential barrier that was quantitatively measured during the high flow condition was Concow Creek Falls. It is located approximately 15 vertical feet above the full-pool level of Lake Oroville, as shown in Figure 5.5-3. Due to significant safety concerns, the passage expert assessment team was unable to obtain quantitative measurements of the potential barrier, or even get sufficiently close to the barrier to estimate its dimensions. However, based on visual comparisons with other barriers of its size and based on the amount of turbulence associated with the waterfall, the expert assessment team concluded that the third barrier evaluated in Concow Creek Falls was likely a passage barrier under the observed flow conditions.

Concow Creek Falls was determined to be impassable by all four salmonids evaluated under the observed high flow conditions. Middle and Upper Concow Creek Falls were both elevation barriers at the observed low flow conditions. Because of the height dimensions of both barriers and because the falls are virtually a straight vertical drop, under high flow conditions both falls would be anticipated to exhibit increased water velocities, but the nature of the barriers and the barrier height would not be anticipated to change with increased flow.

5.5.3 Berry Creek

Description: Berry Creek is a tributary of the North Fork Feather River. The creek is characterized by large bedrock pools separated by cascades and waterfalls.

Assessment at low flow condition: The passage assessment team evaluated Berry Creek during the October 2002 representative low flow evaluation. The conditions at three potential passage barriers (Berry Creek Falls #1, Berry Creek Old Dam, and Berry Creek Falls #2) on Berry Creek during the evaluation are illustrated in Figures 5.5-4 through 5.5.6.

Figure 5.5-4. Berry Creek looking upstream towards Berry Creek Falls #1 at 875 feet msl.

Figure 5.5-5. Berry Creek looking upstream at Berry Creek Old Dam barrier at 899 feet msl, which is presumably an old hydraulic mining dam carved into bedrock.

Figure 5.5-6. Berry Creek looking upstream at Berry Creek Falls #2, a potential barrier above the full-pool level of Lake Oroville.

The characteristics of each of the three potential barriers were measured in the field during the representative low flow condition. Estimated data are presented in Table 5.5-2.

Berry creek was evaluated during both the representative low and high flow conditions. During the low flow conditions, three potential passage barriers were evaluated in Berry Creek, while only the first barrier was assessed (visually) during the representative high flows. The measured physical parameters of the three potential passage barriers are illustrated in Table 5.5-2. Potential Barrier Number One was assessed during both representative conditions and exhibited similar characteristics during each evaluation.

Table 5.5-2. Measured data characteristics of Berry Creek Falls #1 (*a*), Berry Creek Old Dam (*b*), and Berry Creek Falls #2 (*c*), collected during the October 2002 passage barrier assessments.

(*a*) Potential Barrier Number One Berry Creek Falls #1-Elevation 875 feet msl			
Parameter	**Data Notation**	**Collection Method**	**Results and Description**
Vertical Barrier Height	H	M	27 feet
Horizontal Width\Range	X	M	38 feet
Depth of Staging Pool	dpp	M	>15 feet
(*b*) Potential Barrier Number 2Berry Creek Old Dam-Elevation 899 feet msl			
Parameter	**Data Notation**	**Collection Method**	**Results and Description**
Vertical Barrier Height	H	M	5.8 feet
Horizontal Width\Range	X	M	8.5 feet
Depth of Staging Pool	dpp	M	Average of 2 feet; non-uniform substrate which includes several rocks existing in the potential staging area
(*c*) Potential Barrier Number Three, Berry Creek Falls #2-Above Lake Oroville Full-Pool			
Parameter	**Data Notation**	**Collection Method**	**Results and Description**
Vertical Barrier Height	H	M	12 feet
Horizontal Width\Range	X	M	27 feet
Depth of Staging Pool	dpp	M	8 feet

Using barrier height measurements of 27 ft, 5.8 ft, and 12 ft to represent each potential barrier, the falls passage assessment was conducted. Step 1 asks: "Is the vertical change in water surface elevation (H) greater than the maximum height of fish's leap (HL) where θL = 90°F" Using the assumptions and variables defined above in section 4.0, and the data sheet for fall-type barriers, each required size and species combination was analyzed.

- **Anadromous-sized Chinook salmon**: The estimated height of each of the three potential barriers was 27 ft, 5.8 ft, and 12 ft. Using the data sheet for fall-type barriers and the assumptions and variables defined in section 4.0, HL was calculated to be 4.4 ft. Therefore, H>HL and the answer to Step 1 is yes for each of the potential barriers. The analysis suggests that each of the potential barriers is an elevation barrier for anadromous-sized Chinook salmon under the low flow conditions observed in October 2002.

- **Anadromous-sized steelhead**: The estimated height of each of the three potential barriers was 27 ft, 5.8 ft, and 12 ft. Using the data sheet for fall-type barriers and the assumptions and variables defined in section 4.0, HL was calculated to be 6.1 ft. Therefore, for Berry Creek Falls #1 and Berry Creek Falls #2, H>HL and the answer to Step 1 is yes. The analysis suggests that Berry Creek Falls #1 and Berry Creek Falls #2 are elevation barriers for anadromous-sized steelhead under the low flow conditions observed in October 2002. For passage of anadromous-sized steelhead over Berry Creek Old Dam, H<HL, and

the answer to the Step 1 is no. Step 2 for anadromous-sized steelhead passage over Berry Creek Old Dam is presented below.

- **Inland-sized Chinook salmon**: The estimated height of each of the three potential barriers was 27 ft, 5.8 ft, and 12 ft. Using the data sheet for fall-type barriers and the assumptions and variables defined in section 4.0, HL was calculated to be 1.7 ft. Therefore, H>HL and the answer to Step 1 is yes. The analysis suggests that each of the potential barriers is an elevation barrier for inland-sized Chinook salmon under the low flow conditions observed in October 2002.

- **Inland-sized coho salmon**: The estimated height of each of the three potential barriers was 27 ft, 5.8 ft, and 12 ft. Using the data sheet for fall-type barriers and the assumptions and variables defined in section 4.0, HL was calculated to be 1.0 ft. Therefore, H>HL and the answer to Step 1 is yes. The analysis suggests that each of the potential barriers is an elevation barrier for inland-sized coho salmon under the low flow conditions observed in October 2002.

The passage assessment methodology suggests that Berry Creek Falls #1 and Berry Creek Falls #2 are elevation barriers for all species evaluated. The methodology also suggests that Berry Creek Old Dam is an elevation barrier for all species except anadromous-sized steelhead. Step 2 for anadromous-sized steelhead is presented below.

Using a barrier range measurement (X) of 8.5 ft, the falls passage assessment was conducted. Step 2 asks: "Is the horizontal distance from the crest of the falls to the standing wave (X) greater than the horizontal distance of the fish's leap at the highest point of the leap (XL)?" Using the assumptions and variables defined above in section 4.0, and the data sheet for fall-type barriers, anadromous-sized steelhead were analyzed for passage over Berry Creek Old Dam.

- **Anadromous-sized steelhead**: The estimated range of Berry Creek Old Dam was 8.5 ft. Using the data sheet for fall-type barriers and the assumptions and variables defined in section 4.0, XL was calculated to be 4.84 ft. Therefore, for Berry Creek Old Dam, X>XL and the answer to Step 2 is yes.

Because Step 2 is "yes", Step 3 is required. Step 3 asks, "does superimposition of the water surface profile on fish leaping curves suggest that the barrier is passable?". The leaping curve for steelhead is presented below in Figure 5.5-7. If a steelhead jumped 5.8 ft high, the horizontal distance from the origin of the jump at the top of the curve would be 4.84 ft and the leap angle would be 64 degrees, as illustrated by the blue circle. Envisioning the path of the fish's jump around the apex of the curve illustrates that the steelhead with a coefficient of fish condition of 0.75 would not be able to jump the combination of vertical and horizontal components necessary to pass Berry Creek

Old Dam, which is 5.8 ft high and 8.5 ft in range, as illustrated by the yellow circle. Thus, the answer to Step 3 is "no" and the analysis suggests that Berry Creek Old Dam is a horizontal distance barrier.

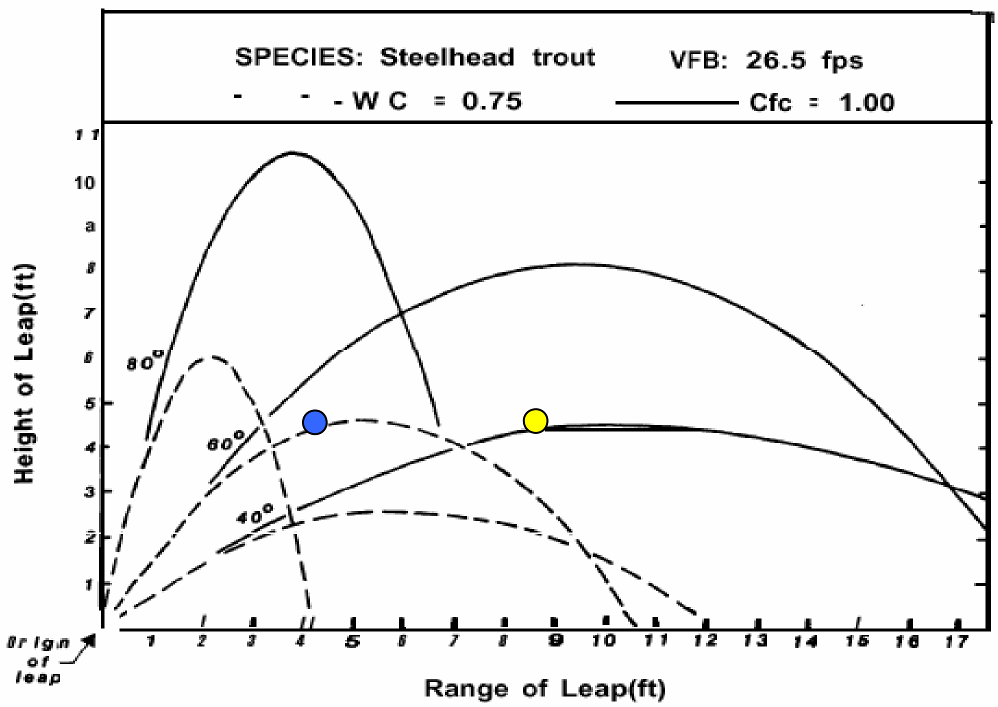


Figure 5.5-7. Steelhead leaping curve, with the blue dot representing the apex of the leaping curve if the jump were to reach 5.8 ft. high, and the yellow dot representing the dimensions of the jump required to pass Berry Creek Old Dam.

The assessment team made several observations during their October 2002 visit to Berry Creek. With regard to Berry Falls #1, the assessment team generally agreed that the vertical and horizontal extent of the falls constituted a complete passage barrier during the observed flow representative conditions. However, because the falls exist within the full-pool elevation of Lake Oroville (875 feet msl), reservoir level conditions could potentially either decrease the vertical and horizontal extent of the falls or completely inundated them. As a result, the assessment team continued upstream to evaluate other upstream barriers.

Berry Creek Old Dam is situated at an elevation of 899 feet msl, and was approximately 200 feet upstream of Berry Creek Falls #1. Berry Creek Old Dam consisted of a waterfall over what appeared to be remnants of an old hydraulic mining dam carved into the bedrock substrate. In addition to the passage assessment suggesting that this barrier was a horizontal distance barrier, the assessment team determined that the non-uniform substrate in the leaping pool would inhibit ideal leaping conditions. Therefore, the assessment team determined that the falls likely represented a passage impediment. However, as with the previous barrier, because the falls exist within an area that could be affected by Lake Oroville full-pool conditions, the assessment team continued the barrier survey upstream on Berry Creek.

The most downstream potential passage barrier assessed on Berry Creek had a crest elevation of approximately 875 feet msl. The expert team generally agreed that the vertical and horizontal extent of the falls constituted a complete passage impediment during the observed flow representative conditions. However, because the falls exist within the full-pool elevation of Lake Oroville, reservoir level conditions could potentially either decrease the vertical and horizontal extent of the falls or completely inundated them, which merited the evaluation of other upstream barriers.

The next potential passage barrier assessed by the expert team existed at an elevation of 899 feet msl, and approximately 200 feet upstream of the previous falls. The barrier consisted of a waterfall over what appeared to be remnants of an old hydraulic mining dam carved into the bedrock substrate. While the passage methodology and physical characteristics of the barrier suggested a potential for passage by a steelhead of optimal condition leaping at an optimal angle, the assessment team determined that the non-uniform substrate in the leaping pool would inhibit ideal leaping conditions. Therefore, the assessment team determined that the falls likely represented a passage impediment. However, as with the previous barrier, because the falls exist within an area that could be affected by Lake Oroville full-pool conditions, and due to the uncertainty regarding the passage conclusion, the expert team continued their barrier survey upstream.

The final potential passage barrier assessed, Berry Creek Falls #2, by the expert team was situated approximately 75 yards upstream of the previous impediment Berry Creek Old Dam. The expert assessment team concluded, based on height and width characteristics, that the waterfall was a complete upstream migration barrier for adult salmonids under the observed low flow conditions. In addition, because the barrier is above the full-pool level of Lake Oroville, its characteristics are not subject to reservoir level conditions; therefore, the barrier likely defines the upstream extent of the migratory reach of Berry Creek.

Assessment at high flow condition: The passage assessment team evaluated Berry Creek Falls #1 during the March 2003 representative high flow evaluation. Because Berry Creek Falls #1 was assessed during both representative high and low flow conditions and exhibited similar characteristics during each evaluation, the assessment team did not evaluate Berry Creek Old Dam and Berry Creek Falls #2 during the March 2003 assessment. The conditions at Berry Creek Falls #1 during the March 2003 evaluation are illustrated in Figure 5.5-8.

Figure 5.5-8. Berry Creek Falls #1 during March 2003 evaluation.

Physical measurements for Berry Creek Falls #1 were very similar as those obtained in October 2002 and represented in Table 5.5-2. Although comparison of Figure 5.5-8 and Figure 5.5-4 illustrate that the volume of water flowing in Berry Creek is increased in March 2003 compared to October 2002, comparison also illustrates that the height and range of the jump required to pass Berry Creek Falls #1 is very similar during both the high flow and low flow condition observations. Because the observations under both high and low flow conditions yielded highly similar physical measurements, the results of the assessment are very similar to the results of the October 2002 assessment, in which the passage assessment methodology suggested that Berry Creek Falls #1 is elevation barriers for all species evaluated.

Overall, although Berry Creek Falls #1 and Berry Creek Old Dam were impassible for all evaluated salmonids at observed low flow conditions, their passage status could change if they become fully inundated when Lake Oroville is at full-pool. At Lake Oroville's full pool elevation, their passage status remains unknown. Berry Creek Falls #2 was impassible at observed low flow conditions and because Berry Creek Falls #2 is outside of the full-pool level of Lake Oroville, it would not be affected directly by reservoir elevations. Although high flow conditions were not directly evaluated, it is anticipated that because of the dimensions of Berry Creek Falls #2, salmonid passage at increased flows would be unlikely. Because the Berry Creek Falls #2 is above the full-pool level of Lake Oroville, its characteristics are not subject to reservoir level conditions; therefore, the barrier likely defines the upstream extent of the migratory reach of Berry Creek. However, extreme flow events could change the nature of the barrier, but under such conditions, water velocities may be high enough to prohibit passage. Berry Creek Falls #2 is anticipated to be a passage barrier to all evaluated salmonids at both low and high flow conditions, recognizing that an absolutely definitive passage barrier assessment would require the reevaluation of Berry Creek during a larger range of hydrologic conditions, including very extreme conditions.

5.5.4 French Creek

Description: French Creek is a relatively large tributary of the North Fork Feather River. The first potential barrier encountered was Lower French Creek Falls, a falls situated approximately 250 meters upstream of the Lake Oroville full-pool elevation (approximately 1 mile upstream of the interface of French Creek and the North Fork arm of Lake Oroville during March 2003 reservoir pool elevation of 828 ft msl).]

Assessment at low flow condition: The passage assessment team evaluated French Creek during the October 2002 representative low flow evaluation. Photos describing the conditions at French Creek during October 2002 are not available. The characteristics of lower French Creek Falls were directly measured in the field during the representative low flow condition. Measured data are presented in Table 5.5-3.

Table 5.5-3. Measured data characteristics of lower French Creek Falls collected during the October 2002 passage barrier assessments.

Parameter	Data Notation	Collection Method	Results and Description
Barrier Height	H	M	10 feet
Horizontal Range	X	M	17 feet
Depth of Staging Pool	dpp	M	5 feet

Using a barrier height measurement of 10 ft, the falls passage assessment was conducted. Step 1 asks: "Is the vertical change in water surface elevation (H) greater than the maximum height of fish's leap (HL) where θL = 90°?" Using the assumptions and variables defined above in section 4.0, and the data sheet for fall-type barriers, each required size and species combination was analyzed.

- **Anadromous-sized Chinook salmon**: The measured height of lower French Creek Falls (H) was 10 ft. Using the data sheet for fall-type barriers and the assumptions and variables defined in section 4.0, HL was calculated to be 4.4 ft. Therefore, H>HL and the answer to Step 1 is yes. The analysis suggests that lower French Creek Falls is an elevation barrier for anadromous-sized Chinook salmon under the low flow conditions observed in October 2002.

- **Anadromous-sized steelhead**: The measured height of lower French Creek Falls (H) was 10 ft. Using the data sheet for fall-type barriers and the assumptions and variables defined in section 4.0, HL was calculated to be 6.1 ft. Therefore, H>HL and the answer to Step 1 is yes. The analysis suggests that lower French Creek Falls is an elevation barrier for anadromous-sized steelhead under the low flow conditions observed in October 2002.

- **Inland-sized Chinook salmon**: The measured height of lower French Creek Falls (H) was 10 ft. Using the data sheet for fall-type barriers and the assumptions and variables defined in section 4.0, HL was calculated to be 1.7 ft. Therefore, H>HL and the answer to Step 1 is yes. The analysis suggests that lower French Creek Falls is an elevation barrier for inland-sized Chinook salmon under the low flow conditions observed in October 2002.

- **Inland-sized coho salmon**: The measured height of lower French Creek Falls (H) was 10 ft. Using the data sheet for fall-type barriers and the assumptions and variables defined in section 4.0, HL was calculated to be 1.0 ft. Therefore, H>HL and the answer to Step 1 is yes. The analysis suggests that lower French Creek Falls is an elevation barrier for inland-sized coho salmon under the low flow conditions observed in October 2002.

The assessment team made several observations during their October 2002 visit to lower French Creek Falls, which was evaluated by members of the expert team during both representative low and high flow conditions. Quantitative measurements were collected at the falls during both low flow and high flow conditions. The assessment team observed that in addition to the height and width restrictions represented at lower French Creek Falls, the water constituting the potential staging area was saturated with entrained air and very turbulent. The assessment team estimated that water velocities in the staging and landing sites were also sufficient to conclude that the falls were impassible to upmigrating adult salmonids during the observed flow conditions. Thus, members of the assessment team deemed lower French Creek Falls impassable by all four salmonids evaluated under the observed low flow conditions.

Assessment at high flow condition: The passage assessment team evaluated lower French Creek Falls during the March 2003 representative high flow evaluation. The conditions at lower French Creek Falls during the evaluation are illustrated in Figures 5.5-9 and 5.5-10.

Figure 5.5-9. Lower French Creek Falls in March 2003.

Figure 5.5-10. NOAA Fisheries biologist Eric Theiss holding his hands 1 ft apart on the 25 ft stadia rod at lower French Creek Falls during the March 2003 assessment.

The characteristics of lower French Creek Falls were directly measured in the field during the representative high flow condition. However, due to significant safety concerns during the representative high flow conditions, only the portion of the waterfall at the extreme river-right location could be measured. Measured data are presented in Table 5.5-4.

Table 5.5-4. Measured data characteristics of lower French Creek Falls collected during the March 2003 passage barrier assessments.

Parameter	Data Notation	Collection Method	Results and Description
Barrier Height	H	M	7 feet
Horizontal Range	X	E	4 to 5 feet (based on photo interpretation)
Depth of Staging Pool	dpp	M	Average 5 to 6 feet, ranging to 10 feet
Depth of Landing Site	d_c	M	4 to 5 inches

Using a barrier height measurement of 7 ft, the falls passage assessment was conducted. Step 1 asks: "Is the vertical change in water surface elevation (H) greater than the maximum height of fish's leap (HL) where θL = 90°?" Using the assumptions and variables defined above in section 4.0, and the data sheet for fall-type barriers, each required size and species combination was analyzed.

- **Anadromous-sized Chinook salmon**: The measured height of lower French Creek Falls (H) was 7 ft. Using the data sheet for fall-type barriers and the assumptions and variables defined in section 4.0, HL was calculated to be 4.4 ft. Therefore, H>HL and the answer to Step 1 is yes. The analysis suggests that lower French Creek Falls is an elevation barrier for anadromous-sized Chinook salmon under the high flow conditions observed in March 2003.

- **Anadromous-sized steelhead**: The measured height of lower French Creek Falls (H) is 7 ft. Using the data sheet for fall-type barriers and the assumptions and variables defined in section 4.0, HL was calculated to be 6.1 ft. Therefore, H>HL and the answer to Step 1 is yes. The analysis suggests that lower French Creek Falls is an elevation barrier for anadromous-sized steelhead under the high flow conditions observed in March 2003.

- **Inland-sized Chinook salmon**: The measured height of lower French Creek Falls (H) is 7 ft. Using the data sheet for fall-type barriers and the assumptions and variables defined in section 4.0, HL was calculated to be 1.7 ft. Therefore, H>HL and the answer to Step 1 is yes. The analysis suggests that lower French Creek Falls is an elevation barrier for inland-sized Chinook salmon under the high flow conditions observed in March 2003.

- **Inland-sized coho salmon**: The measured height of lower French Creek Falls (H) is 7 ft. Using the data sheet for fall-type barriers and the assumptions and variables defined in section 4.0, HL was calculated to be 1.0 ft. Therefore, H>HL and the answer to Step 1 is yes. The analysis suggests that lower French Creek Falls is an elevation barrier for inland-sized coho salmon under the high flow conditions observed in March 2003.

The assessment team made several observations during their March 2003 visit to lower French Creek Falls. The March 2003 barrier evaluation team only collected metrics on the portion of the falls existing in an extreme river-right location because this section of the falls represented the most plausibly passable portion of the creek during the observed conditions. In addition to the physical parameters illustrated in Table 5.5-4, the assessment team also considered the air saturation of the water in the staging pool in determining the probability of passage at the falls. The extreme river-right portion of the waterfall merited substantial discussion; however, after careful consideration, the assessment team deemed this portion of the waterfall likely impassable due to several factors, including the relatively small (approximately 5 percent) attraction flow captured by the waterfall, and the unlikelihood of a salmonid of the appropriate condition factor being able to leap over the barrier based on the passage methodology leaping curves. The passage expert team concluded that the main portion of the falls was completely impassable at the observed high flow condition. Thus, members of the assessment team deemed lower French Creek Falls impassable by all four salmonids evaluated under the observed high flow conditions. Under an extreme high flow event, it may be possible that lower French Creek Falls could become inundated or its characteristics could change from falls to chute-like. Under these types of conditions, water velocities would likely cause increased air entrainment and could be sufficiently extreme to inhibit the upstream passage of migrating fish. Overall, lower French Creek Falls was determined to be likely impassable for all four salmonids evaluated, recognizing that an absolutely definitive passage barrier assessment would require the reevaluation during an extreme range of hydrologic conditions.

5.5.5 Chino Creek

Description: Chino Creek is a small tributary of the North Fork Feather River located approximately 2 miles downstream of Big Bend Dam. Two potential barriers were evaluated, Chino Creek Falls #1, located at the interface between Chino Creek and the Lake Oroville full pool level, and Chino Creek Falls #2, located approximately 150 yards upstream of the interface between Chino Creek and Lake Oroville full-pool level. Chino Creek was evaluated by the expert team during the October 2002 representative low flow conditions, but was not reevaluated during relatively higher flow conditions. The expert team quantitatively assessed two potential passage barriers in the Chino Creek drainage. The first passage barrier was located at the interface between Chino Creek and the Lake Oroville full-pool level. During the observed representative low flows, the falls was approximately 20 to 25 feet in height. The pool at the base of the falls was greater than 10 feet deep and fish were observed there during the passage evaluation. Downstream of the pool, Chino Creek formed a very shallow cascade down a hillside, and eventually poured into the North Fork Feather River. The waterfall was obviously impassible under the observed conditions. However, because the height of the falls would become significantly diminished when Lake Oroville reached a full-pool level, perhaps falling to only a few feet, the passage assessment team decided to survey the upstream reaches of Chino Creek for other potential passage barriers.

Assessment at low flow condition: The passage assessment team evaluated Chino Creek Falls #1 and Chino Creek Falls #2 during the October 2002 representative low flow evaluation. The conditions at both barriers during the October 2002 evaluation are illustrated in Figures 5.5-11 and 5.5-12.

Figure 5.5-11. Chino Creek Falls #1 looking up at the waterfall from its downstream base; note the Lake Oroville high pool mark exists at approximately the top of the broad flat rock surface on the right of the picture.

Figure 5.5-12. Chino Creek Falls #2 during March 2003.

The characteristics of Chino Creek Falls #1 and Chino Creek Falls #2 were directly measured in the field during the representative low flow condition. Measured data are presented in Table 5.5-5.

Table 5.5-5. Measured data characteristics of Chino Creek Falls #1 (*a*), and Chino Creek Falls #2 (*b*) collected during the October 2002 passage barrier assessments.

Parameter	Data Notation	Collection Method	Results and Description
(*a*) Chino Creek Falls #1 - interface between Chino Creek and the Lake Oroville full-pool level			
Barrier Height	H	M	20-25 feet
Depth of Staging Pool	dpp	M	>10 feet
(*b*) Chino Creek Falls #2 - approximately 150 yards upstream of the interface between Chino Creek and Lake Oroville full-pool level			
Barrier Height	H	M	14.2 feet
Depth of Staging Pool	dpp	M	3 feet

Using barrier height measurements of 20 ft and 14.2 ft, the falls passage assessment was conducted. Step 1 asks: "Is the vertical change in water surface elevation (H) greater than the maximum height of fish's leap (HL) where θL = 90°?" Using the assumptions and variables defined above in section 4.0, and the data sheet for fall-type barriers, each required size and species combination was analyzed.

- **Anadromous-sized Chinook salmon**: The measured height of Chino Creek Falls #1 and Chino Creek Falls #2 (H) was 20 ft and 14.2 ft, respectively. Using the data sheet for fall-type barriers and the assumptions and variables defined in section 4.0, HL was calculated to be 4.4 ft. Therefore, for each of the potential barriers, H>HL and the answer to Step 1 is yes. The analysis suggests that Chino Creek Falls #1 and Chino Creek Falls #2 are both elevation barriers for anadromous-sized Chinook salmon under the low flow conditions observed in October 2002.

- **Anadromous-sized steelhead**: The measured height of Chino Creek Falls #1 and Chino Creek Falls #2 (H) was 20 ft and 14.2 ft, respectively. Using the data sheet for fall-type barriers and the assumptions and variables defined in section 4.0, HL was calculated to be 6.1 ft. Therefore, for each of the potential barriers, H>HL and the answer to Step 1 is yes. The analysis suggests that Chino Creek Falls #1 and Chino Creek Falls #2 are both elevation barriers for anadromous-sized steelhead under the low flow conditions observed in October 2002.

- **Inland-sized Chinook salmon**: The measured height of Chino Creek Falls #1 and Chino Creek Falls #2 (H) was 20 ft and 14.2 ft, respectively. Using the data sheet for fall-type barriers and the assumptions and variables defined in section 4.0, HL was calculated to be 1.7 ft. Therefore, for each of the potential barriers, H>HL and the answer to Step 1 is yes. The analysis suggests that Chino Creek Falls #1 and Chino Creek Falls #2 are both elevation barriers for inland-sized Chinook salmon under the low flow conditions observed in October 2002.

- **Inland-sized coho salmon**: The measured height of Chino Creek Falls #1 and Chino Creek Falls #2 (H) was 20 ft and 14.2 ft, respectively. Using the data sheet for fall-type barriers and the assumptions and variables defined in section 4.0, HL was calculated to be 1.0 ft. Therefore, for each of the potential barriers, H>HL and the answer to Step 1 is yes. The analysis suggests that Chino Creek Falls #1 and Chino Creek Falls #2 are both elevation barriers for inland-sized coho salmon under the low flow conditions observed in October 2002.

The assessment team made several observations during their October 2002 visit to Chino Creek. Fish were observed in the pool at the base of Chino Creek Falls #1 during the passage evaluation. Downstream of the pool, Chino Creek formed a very shallow cascade down a hillside, and eventually poured into the North Fork Feather

River. The assessment team determined that Chino Creek Falls #1 was obviously impassible under the observed conditions. However, because the height of the falls would become significantly diminished when Lake Oroville reached a full-pool level, perhaps falling to only a few feet, the passage assessment team continued to survey the upstream reaches of Chino Creek for other potential passage barriers. The second potential passage barrier evaluated in Chino Creek during the October 2002 assessment, Chino Creek Falls #2, is located approximately 150 yards upstream of the interface between Chino Creek and Lake Oroville full-pool level. The initial waterfall at this location was measured at approximately 14.2 feet in vertical height, and the pool at the base of the falls was 3 feet deep. In addition to the metrics presented in Table 5.5-5, a series of substantial cascades and pools continue upstream of the waterfall for approximately 25 yards. The passage assessment team determined that the falls would not be passable during the observed representative low flow conditions, and because the falls existed well upstream of the interface with Lake Oroville, the characteristics of the falls would not be influence by reservoir level conditions. Because increased flows would likely result in increased water velocities and increased turbidity, but would not likely change the overall dimensions of Chino Creek Falls #2, it is not anticipated that Chino Creek Falls #2 would become passable under higher flows than those observed during the October 2002 evaluation. Thus, members of the assessment team concluded that this barrier is the likely upstream extent of the migratory zone within Chino Creek. Overall, Chino Creek Falls #2 was determined to be likely impassable for all four salmonids evaluated, recognizing that an absolutely definitive passage barrier assessment would require the reevaluation of Chino Creek during an extreme range of hydrologic conditions.

5.5.6 Stony Creek

Description: Stony Creek is a small tributary of the North Fork Feather River located approximately 0.25 miles upstream of Chino Creek.

Assessment at low flow condition: The passage assessment team evaluated Stony Creek during the October 2002 representative low flow evaluation. During the October 2002 evaluation, Stony Creek appeared to have lost its flow underground, as the mouth of the creek was dry, and a spring existed beneath a rock retaining wall approximately 30 feet upstream of the streambed. The expert team determined that if Stony Creek retained a sufficient flow, the first potential barrier would be located at the interface between Stony Creek and the Lake Oroville full-pool level. The conditions at the interface between Stony Creek and the Lake Oroville full-pool level during the evaluation are illustrated in Figure 5.5-13.

Figure 5.5-13. Stony Creek looking down from the top of the would-be waterfall which, when watered, would dump into Lake Oroville; note that the streambed was dry in this October 2002 photograph.

The characteristics of the would-be Stony Creek Falls were directly measured in the field during the representative low flow condition. Measured data are presented in Table 5.5-6.

Table 5.5-6. Measured data characteristics of the would-be Stony Creek Falls collected during the October 2002 passage barrier assessments.

Parameter	Data Notation	Collection Method	Results and Description
Barrier Height	H	M	20-25 feet

Using a barrier height measurement of 20 ft, the falls passage assessment was conducted. Step 1 asks: "Is the vertical change in water surface elevation (H) greater than the maximum height of fish's leap (HL) where θL = 90°?" Using the assumptions and variables defined above in section 4.0, and the data sheet for fall-type barriers, each required size and species combination was analyzed.

- **Anadromous-sized Chinook salmon**: The measured height of Stony Creek Falls (H) was 20 ft. Using the data sheet for fall-type barriers and the assumptions and variables defined in section 4.0, HL was calculated to be 4.4 ft. Therefore, H>HL and the answer to Step 1 is yes. The analysis suggests that Stony Creek Falls is an elevation barrier for anadromous-sized Chinook salmon under the low flow conditions observed in October 2002.

- **Anadromous-sized steelhead**: The measured height of Stony Creek Falls (H) was 20 ft. Using the data sheet for fall-type barriers and the assumptions and variables defined in section 4.0, HL was calculated to be 6.1 ft. Therefore, H>HL and the answer to Step 1 is yes. The analysis suggests that Stony Creek Falls is an elevation barrier for anadromous-sized steelhead under the low flow conditions observed in October 2002.

- **Inland-sized Chinook salmon**: The measured height of Stony Creek Falls (H) was 20 ft. Using the data sheet for fall-type barriers and the assumptions and variables defined in section 4.0, HL was calculated to be 1.7 ft. Therefore, H>HL and the answer to Step 1 is yes. The analysis suggests that Stony Creek Falls is an elevation barrier for inland-sized Chinook salmon under the low flow conditions observed in October 2002.

- **Inland-sized coho salmon**: The measured height of Stony Creek Falls (H) was 20 ft. Using the data sheet for fall-type barriers and the assumptions and variables defined in section 4.0, HL was calculated to be 1.0 ft. Therefore, H>HL and the answer to Step 1 is yes. The analysis suggests that Stony Creek Falls is an elevation barrier for inland-sized coho salmon under the low flow conditions observed in October 2002.

The assessment team made several observations during their October 2002 visit to Stony Creek Falls. The expert team evaluated Stony Creek during the representative low flow conditions in October 2002, but did not reevaluate the stream during relatively higher flow conditions. During the October 2002 evaluation, Stony Creek appeared to have lost its flow underground, as the mouth of the creek was dry, and a spring existed beneath a rock retaining wall approximately 30 feet upstream of the streambed. The expert team determined that if Stony Creek retained a sufficient flow, the first potential barrier would be located at the interface between Stony Creek and the Lake Oroville full-pool level. The expert team determined, based on direct measurement, water would have fallen approximately 20 to 25 feet from this location. Under the observed representative low flow conditions, it would have been impossible for a fish to enter Stony Creek, even if it had been exhibiting a flow into Lake Oroville. Members of the assessment team deemed Stony Creek Falls impassable by all four salmonids evaluated under the observed low flow conditions.

Assessment at high flow condition: Stony Creek was not evaluated by the fish passage assessment team during the March 2003 representative high flow passage assessment due to the lack of any flow in the tributary at low flow observations. Overall, Stony Creek Falls was determined to be impassable for all four salmonids evaluated at low flow conditions while the passage status at high flow conditions remains unknown, recognizing that an absolutely definitive passage barrier assessment would require the reevaluation of Stony Creek during an extreme range of hydrologic conditions.

5.5.7 Sucker Run Creek

Description: Sucker Run Creek is a tributary of the South Fork Feather River, with the confluence located approximately 0.5 miles downstream of Ponderosa Diversion Dam. Because the several potential barriers within the fluctuation zone of Lake Oroville were qualitatively evaluated and determined to be potentially passable by the assessment team, these barriers will not be presented. Rather, the quantitative analysis focuses on Sucker Run Creek Boulder Falls, located approximately 1 mile upstream of the interface between Lake Oroville and Sucker Run Creek during the October 2002 evaluation. Sucker Run Boulder Falls consisted of several small waterfalls, cascading through a complex conglomeration of large boulders and woody debris. The Sucker Run drainage was surveyed for potential upstream migration barriers during both the representative low and high flow conditions. In total, three potential migration barriers were identified and evaluated. The most downstream potential migration barrier in Sucker Run Creek was located approximately 40 vertical feet below the Lake Oroville full-pool level. The potential barrier was only evaluated during the October 2002 assessment. While the passage team did not quantitatively measure the characteristics of the barrier, they determined that it would be difficult for a fish to maneuver the impediment due to the complex collection of boulders and debris blocking passage. Still, due its location, the passage assessment team did not make any definitive conclusion regarding this barrier and continued evaluation upstream.

Assessment at low flow condition: The passage assessment team evaluated Sucker Run Creek Boulder Falls during the October 2002 representative low flow evaluation. The conditions at Sucker Run Creek Boulder Falls during the October 2002 evaluation are illustrated in Figure 5.5-14, Figure 5.5-15, Figure 5.5-16, and Figure 5.5-17.

Figures 5.5-14. Looking upstream at Sucker Run Creek Boulder Falls while E. See prepares to measure falls using stadia rod.

Figure 5.5-15. DWR biologist E. See measuring Sucker Run Creek Boulder Falls; note that red numbers on the stadia rod represent feet.

Figure 5.5-16. Landing conditions for Sucker Run Creek Boulder Falls; note branch (left), boulder (right) and Dave White's knee (middle) for scale.

Figure 5.5-17. Eric Theiss, Eric See, and Dave White discuss conditions at Sucker Run Creek Boulder Falls.

The characteristics of Sucker Run Creek Boulder Falls were directly measured in the field during the representative low flow condition. Measured data are presented in Table 5.5-7.

Table 5.5-7. Measured data characteristics of Sucker Run Creek Boulder Falls collected during the October 2002 passage barrier assessments.

Parameter	Data Notation	Collection Method	Results and Description
Barrier Height	H	M	4.1 feet
Horizontal Range	X	M	7.7 feet

Using a barrier height measurement of 4.1 ft, the falls passage assessment was conducted. Step 1 asks: "Is the vertical change in water surface elevation (H) greater than the maximum height of fish's leap (HL) where $\theta L = 90°$?" Using the assumptions and variables defined above in section 4.0, and the data sheet for fall-type barriers, each required size and species combination was analyzed.

- **Anadromous-sized Chinook salmon**: The measured height of Sucker Run Creek Boulder Falls (H) was 4.1 ft. Using the data sheet for fall-type barriers and the assumptions and variables defined in section 4.0, HL was calculated to be 4.4 ft. Therefore, H<HL and the answer to Step 1 is no. Step 2 for anadromous-sized Chinook salmon passage over Sucker Run Creek Boulder Falls is presented below.

- **Anadromous-sized steelhead**: The measured height of Sucker Run Creek Boulder Falls (H) was 4.1 ft. Using the data sheet for fall-type barriers and the assumptions and variables defined in section 4.0, HL was calculated to be 6.1 ft. Therefore, H<HL and the answer to Step 1 is no. Step 2 for anadromous-sized steelhead passage over Sucker Run Creek Boulder Falls is presented below.

- **Inland-sized Chinook salmon**: The measured height of Sucker Run Creek Boulder Falls (H) was 4.1 ft. Using the data sheet for fall-type barriers and the assumptions and variables defined in section 4.0, HL was calculated to be 1.7 ft. Therefore, H>HL and the answer to Step 1 is yes. The analysis suggests that Sucker Run Creek Boulder Falls is an elevation barrier for inland-sized Chinook salmon under the low flow conditions observed in October 2002.

- **Inland-sized coho salmon**: The measured height of Sucker Run Creek Boulder Falls (H) was 4.1 ft. Using the data sheet for fall-type barriers and the assumptions and variables defined in section 4.0, HL was calculated to be 1.0 ft. Therefore, H>HL and the answer to Step 1 is yes. The analysis suggests that Sucker Run Creek Boulder Falls is an elevation barrier for inland-sized coho salmon under the low flow conditions observed in October 2002.

The passage assessment methodology suggests that Sucker Run Creek Boulder Falls is an elevation barriers for inland-sized Chinook salmon and inland-sized coho salmon. The methodology also suggests that Sucker Run Creek Boulder Falls is not an elevation barrier for anadromous-sized Chinook salmon and anadromous-sized steelhead. Step 2 for anadromous-sized Chinook salmon and steelhead is presented below.

Using a barrier range measurement (X) of 7.7 ft, the falls passage assessment was conducted. Step 2 asks: "Is the horizontal distance from the crest of the falls to the standing wave (X) greater than the horizontal distance of the fish's leap at the highest point of the leap (XL)?" Using the assumptions and variables defined above in section 4.0, and the data sheet for fall-type barriers, anadromous-sized Chinook salmon and steelhead were analyzed for passage over Sucker Run Creek Boulder Falls.

- **Anadromous-sized Chinook salmon**: The estimated range of Sucker Run Creek Boulder Falls was 7.7 ft. Using the data sheet for fall-type barriers and the assumptions and variables defined in section 4.0, XL was calculated to be 3.9 ft. Therefore, for Berry Creek Old Dam, X>XL and the answer to Step 2 is yes.

- **Anadromous-sized steelhead**: The estimated range of Sucker Run Creek Boulder Falls was 7.7 ft. Using the data sheet for fall-type barriers and the assumptions and variables defined in section 4.0, XL was calculated to be 5.5 ft. Therefore, for Berry Creek Old Dam, X>XL and the answer to Step 2 is yes.

Because for both species, Step 2 is "yes", Step 3 is required. Step 3 asks, "does superimposition of the water surface profile on fish leaping curves suggest that the barrier is passable?" The leaping curve for Chinook salmon is presented below in Figure 5.5-18 and the leaping curve for steelhead is presented below in Figure 5.5-19. If a Chinook salmon jumped 4.1 ft high in order to pass Sucker Run Creek Boulder Falls, the horizontal distance from the origin of the jump at the top of the curve would be 3.9 ft and the leap angle would be 58 degrees, as illustrated by the blue circle in Figure 5.5-18. Envisioning the path of the fish's jump around the apex of the Chinook salmon leaping curve illustrates that a Chinook salmon with a coefficient of fish condition of 0.75 would not be able to jump the combination of vertical and horizontal components necessary to pass Sucker Run Creek Boulder Falls, which is 4.1 ft high and 7.7 ft in range, as illustrated by the yellow circle in Figure 5.5-18. Thus, the answer to Step 3 is "no" and the analysis suggests that Sucker Run Creek Boulder Falls is a horizontal distance barrier for anadromous-sized Chinook salmon.

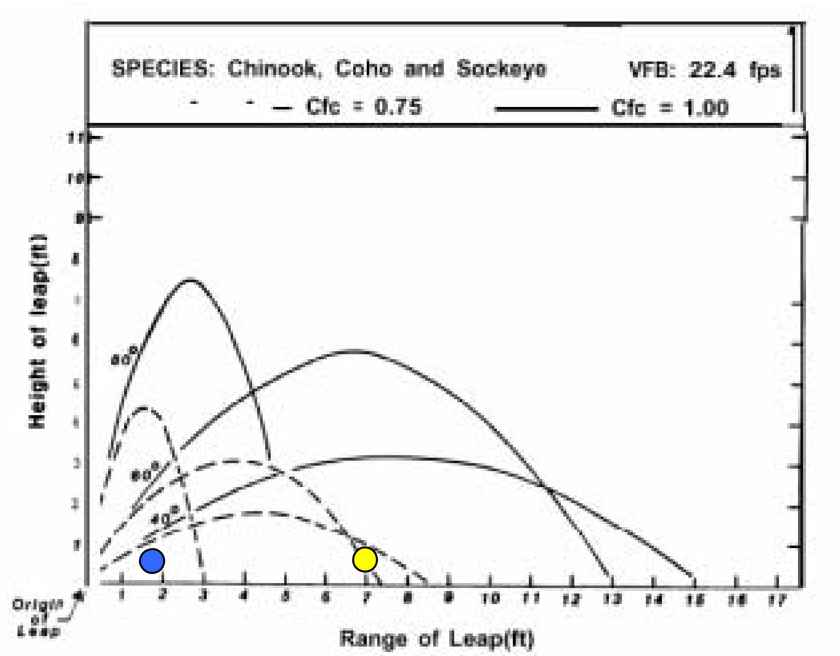


Figure 5.5-18. Chinook salmon leaping curve, with the blue dot representing the apex of the leaping curve if the jump were to reach 4.1 ft. high, and the yellow dot representing the dimensions of the jump required to pass Sucker Run Creek Boulder Falls.

If a steelhead jumped 4.1 ft high in order to pass Sucker Run Creek Boulder Falls, the horizontal distance from the origin of the jump at the top of the curve would be 5.5 ft and the leap angle would be 58 degrees, as illustrated by the blue circle in Figure 5.5-19.

Although the Sucker Run Creek Boulder Falls dimensions are the same as in Figure 5.5-18, steelhead can jump at the same angle as a Chinook salmon and obtain a further range (in this case, 5.5 ft as opposed to 3.9 ft) because of their increased burst speed. Envisioning the path of the fish's jump around the apex of the steelhead leaping curve illustrates that a steelhead with a coefficient of fish condition of 0.75 would fall just short of the combination of vertical and horizontal components necessary to pass Sucker Run Creek Boulder Falls, which is 4.1 ft high and 7.7 ft in range, as illustrated by the yellow circle in Figure 5.5-19. Thus, the answer to Step 3 is "no" and the analysis suggests that Sucker Run Creek Boulder Falls is a horizontal distance barrier for anadromous-sized steelhead.

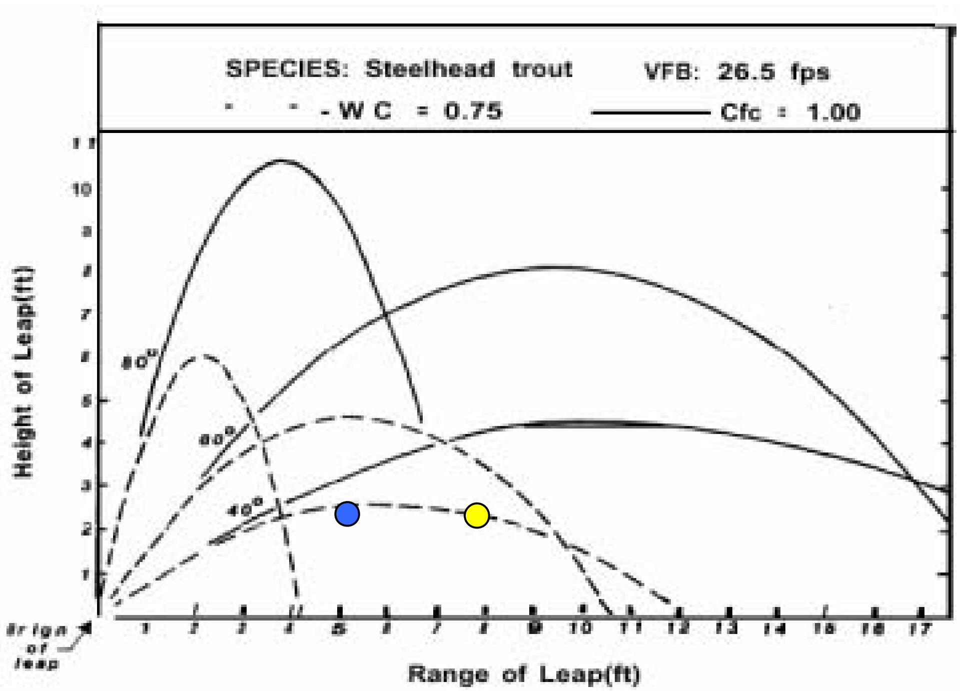


Figure 5.5-19. Steelhead leaping curve.
Note: Blue dot represents the apex of the leaping curve if the jump were to reach 4.1 ft. high, and the yellow dot represents the dimensions of the jump required to pass Sucker Run Creek Boulder Falls.

The assessment team made several observations during their October 2002 visit to Sucker Run Creek Boulder Falls. While the passage methodology leaping curves illustrated that a steelhead would fall just short of being able to pass this barrier, a multitude of factors combined to suggest that the barrier would be impassible under the observed representative low flow conditions. The passage team concluded that overhanging boulders would likely preclude a Chinook salmon or steelhead from utilizing the appropriate leap angle, that the expected staging and landing areas characteristics were insufficient, and that the water within and around the waterfalls was saturated with entrained air, all of which would serve to reduce potential passage efficiency below the baseline expected for a salmonids of appropriate coefficient of fish condition. Thus, members of the assessment team determined that Sucker Run Creek

Boulder Falls is likely impassable to immigrating salmonids during representative low flow conditions.

The second potential passage barrier encountered by the passage assessment team, referred to as Sucker Run Creek 2, was a cascade/falls complex located approximately 1 mile upstream of the interface between Lake Oroville and Sucker Run Creek, during the October 2002 pool conditions. The potential barrier was assessed during both representative low and high flow conditions, although each evaluation resulted in very similar results.

Assessment at high flow condition: The passage assessment team evaluated Sucker Run Creek Boulder Falls during the March 2003 representative high flow evaluation. The conditions at Sucker Run Creek Boulder Falls during the March 2003 evaluation are illustrated in Figure 5.5-20.

Figure 5.5-20. Sucker Run Creek Boulder Falls during March 2003 evaluation; note increased water velocity compared to similar photographs taken at Sucker Run Creek Boulder Falls during the October 2002 assessment.

Physical measurements for Sucker Run Creek Boulder Falls were very similar as those obtained in October 2002 and represented in Table 5.5-7. Although comparison of Figure 5.5-20 and Figure 5.5-15 illustrate that the volume of water flowing through Sucker Run Creek Boulder Falls is increased in March 2003 compared to October 2002, comparison also illustrates that the height and range of the jump required to pass Sucker Run Creek Boulder Falls is similar during both the high flow and low flow condition observations. Because the observations under both high and low flow conditions yielded highly similar physical measurements, the results of the assessment are very similar to the results of the October 2002 assessment, in which the passage assessment methodology suggested that Sucker Run Creek Boulder Falls is an elevation barrier for inland-sized salmonid species and a horizontal distance barrier for anadromous-sized salmonids. As in the October 2002 evaluation, the passage team concluded that overhanging boulders would likely preclude a Chinook salmon or steelhead from utilizing the appropriate leap angle, that the expected staging and landing areas characteristics were insufficient, and that the water within and around the waterfalls was saturated with entrained air, all of which would serve to reduce potential passage efficiency below the baseline expected for a salmonids of appropriate coefficient of fish condition. Thus, members of the assessment team determined that Sucker Run Creek Boulder Falls is impassable to salmonids during representative high flow conditions.

Overall, Sucker Run Creek Boulder Falls was determined to be impassible at representative high and low flow conditions. Although is it conceivable that during an extreme high flow event sufficient water could be present to inundate the entire falls, the water velocities under those conditions would be anticipated to be sufficient to inhibit passage. Specific field investigations under such an extreme condition would be required to evaluate passability at extremely high flows. Therefore, Sucker Run Creek Boulder Falls was deemed likely impassible, recognizing that an absolutely definitive passage barrier assessment would require the reevaluation during a larger range of hydrologic conditions, including very extreme conditions. The barrier at this location consists of several small waterfalls, cascading through a complex conglomeration of large boulders and woody debris. During the October 2002 conditions, the most apparent waterfall in the complex was measured at approximately 4.1 feet in height and 7.7 feet in horizontal width. While the passage methodology leaping curves illustrated that a strong steelhead may be able to pass this barrier, a multitude of factors combined to suggest that the barrier would be impassible under the observed representative low flow conditions. The passage team concluded that overhanging boulders would likely preclude the appropriate jump angle, the expected staging and landing areas characteristics were insufficient, and the water within and around the waterfalls was saturated with entrained air. It is therefore likely that the debris-jam complex is likely impassable to upmigrating salmonids during representative low and high flow conditions.

The final potential passage barrier evaluated in the Sucker Run Creek drainage was located approximately 1 mile upstream of the previously described barrier, and was referred to as Sucker Run Creek 2. The barrier was only assessed during the March 2003 evaluation. The evaluated barrier was characterized by a large cascade/fall structure, with an initial waterfall and a turbulent potential holding pool, followed by a series of turbulent cascades/falls. The initial waterfall was the most significant potential obstacle. The measured parameters of the barrier are illustrated in Table 5.5-8.

Table 5.5-8. Measured data characteristics of the most upstream potential barrier on Sucker Run Creek collected during the March 2003 passage barrier assessment.

Parameter	Data Notation	Collection Method	Results and Description
Vertical Height	H	M	Initial falls approximately 4.9 feet
Horizontal Width	X	M	Initial falls approximately 9.2 feet
Depth of Staging Pool	dpp	M	3.8 feet
Depth of Landing Site	d_c	M	1.1 feet within potential mid-structure holding pool

In addition to the measure parameters in Table 5.5-8, the passage expert team also determined that the depth of the water cascading down the rock face was only a few inches. When combined with the relatively significant velocity and cascade angle, the depth of the cascading water would make it unlikely that an upmigrating fish could swim up the rock face, meaning that passage of this initial barrier passage would have to be completed in just one jump. The passage assessment team determined that a fish of the appropriate condition factor would have a very difficult time traversing the barrier. However, upon further investigation, the passage team identified two smaller stepping waterfalls beneath overhanging rocks river-left of the main barrier. These waterfalls exhibited great physical complexity in the form of instream debris and captured only a small proportion of the total river flow, but appeared to be of passable dimensions and characteristics. Therefore, the passage expert team generally concluded that while an upmigrating fish of sufficient size and condition may potentially pass the barrier complex via the main cascade/falls, the two smaller river-left waterfalls provide a much more realistic passage opportunity.

5.5.8 Fall River

Description: The Fall River is a tributary to the Middle Fork Feather River. Two potential barriers on the Fall River were assessed, Fall River Falls and Feather Falls. Fall River Falls is located approximately 410 ft upstream of the high water mark of Lake Oroville. Feather Falls is located upstream of Fall River Falls.

Assessment at low flow condition: DWR biologist Eric See evaluated the Fall River Falls on July 31, 2002 at a representative low flow condition. The conditions at Fall River Falls during the July 2002 evaluation are illustrated in Figure 5.5-21. Feather Falls was not visited during the low flow condition. However, a photograph of Feather Falls, which is a well-known area landmark as it is the sixth tallest waterfall in the United States, is included for reference in Figure 5.5-22.

Figure 5.5-21. Fall River Falls in July 2002. The stadia rod is extended to 15 ft and is in front of the falls.

Figure 5.5-22. Feather Falls, dropping 640 feet.

The characteristics of Fall River Falls were estimated in the field during the representative low flow condition. The characteristics of Feather Falls were taken from existing literature describing Feather Falls. Estimated and collected data are presented in Table 5.5-9.

Table 5.5-9. Estimated data characteristics of Fall River Falls (*a*) collected on July 31, 2002 and data from the literature describing Feather Falls (*b*).

Parameter	Data Notation	Collection Method	Results and Description
(*a*) Fall River Falls			
Barrier Height	H	E	20 feet
(*b*) Feather Falls			
Barrier Height	H	L	640 feet

Using barrier height measurements of 20 ft and 640 ft, the falls passage assessment was conducted. Step 1 asks: "Is the vertical change in water surface elevation (H) greater than the maximum height of fish's leap (HL) where θL = 90°?" Using the assumptions and variables defined above in section 4.0, and the data sheet for fall-type barriers, each required size and species combination was analyzed.

- **Anadromous-sized Chinook salmon**: The measured heights of Fall River Falls and Feather Falls (H) were 20 ft and 640 ft, respectively. Using the data sheet for fall-type barriers and the assumptions and variables defined in section 4.0, HL was calculated to be 4.4 ft. Therefore, for both Fall River Falls and Feather Falls, H>HL and the answer to Step 1 is yes. The analysis suggests that Fall River Falls and Feather Falls are elevation barriers for anadromous-sized Chinook salmon under the low flow conditions observed in July 2002.

- **Anadromous-sized steelhead**: The measured heights of Fall River Falls and Feather Falls (H) were 20 ft and 640 ft, respectively. Using the data sheet for fall-type barriers and the assumptions and variables defined in section 4.0, HL was calculated to be 6.1 ft. Therefore, for both Fall River Falls and Feather Falls, H>HL and the answer to Step 1 is yes. The analysis suggests that Fall River Falls and Feather Falls are elevation barriers for anadromous-sized steelhead under the low flow conditions observed in July 2002.

- **Inland-sized Chinook salmon**: The measured heights of Fall River Falls and Feather Falls (H) were 20 ft and 640 ft, respectively. Using the data sheet for fall-type barriers and the assumptions and variables defined in section 4.0, HL was calculated to be 1.7 ft. Therefore, for both Fall River Falls and Feather Falls, H>HL and the answer to Step 1 is yes. The analysis suggests that Fall River Falls and Feather Falls are elevation barriers for inland-sized Chinook salmon under the low flow conditions observed in July 2002.

- **Inland-sized coho salmon**: The measured heights of Fall River Falls and Feather Falls (H) were 20 ft and 640 ft, respectively. Using the data sheet for fall-type barriers and the assumptions and variables defined in section 4.0, HL was calculated to be 1.0 ft. Therefore, for both Fall River Falls and Feather Falls, H>HL and the answer to Step 1 is yes. The analysis suggests that Fall River Falls and Feather Falls are elevation barriers for inland-sized coho salmon under the low flow conditions observed in July 2002.

The analysis suggests that Fall River Falls is impassable by all four salmonids evaluated under the observed low flow conditions. Feather Falls, dropping 640 ft is clearly impassible under any flow conditions.

Assessment at high flow condition: Fall River Falls was not visited at a representative high flow condition. However, it may be possible to use the collected metrics to suggest passage status at flows which were not observed. Because Fall River Falls is upstream of the influence of Lake Oroville high pool mark, Fall River Falls will not have altered dimensions resulting from changes in the elevation of Lake Oroville. Therefore, the height of the base pool of Fall River Falls under high flow conditions would not be anticipated to be higher than those represented at low flow conditions. Under an extreme high flow event, it may be possible for Fall River Falls to become more chute-like as a result of further inundation. Under these types of conditions, water velocities would likely cause increased air entrainment and could be sufficiently extreme to prohibit the upstream passage of migrating fish. Specific field investigations under these condition would be required to evaluate passability at extremely high flows. Overall, Fall River Falls was determined to be likely impassable for all four salmonids evaluated, recognizing that an absolutely definitive passage barrier assessment would require the reevaluation of Fall River Falls during an extreme range of hydrologic conditions.

Although Feather Falls was not visited at a representative high flow, it is clearly impassible under any flow conditions with a total vertical drop of 640 ft.

5.5.9 Frey Creek

Description: Frey Creek is a cascading stream over bedrock step-pools, which is a tributary to the Middle Fork Arm of Lake Oroville.

Assessment at low flow condition: DWR biologist Eric See evaluated Frey Creek Cascade on July 31, 2002 to assess a representative low flow on Frey Creek (E. See, DWR, pers. comm.). The conditions at Frey Creek Cascade during the evaluation are illustrated in Figure 5.5-23.

Figure 5.5-23. Frey Creek Cascades on July 31, 2002.

Due to significant safety and access concerns, it was not possible to obtain quantitative measurements of Frey Creek Cascades, or even get sufficiently close to the barrier to estimate its total dimensions or dimensions of its components. However, based on visual comparisons with other barriers of its size and based on the lack of staging and landing areas due to small amount of flow, vertical and horizontal distance of particular jumps, and the combination of jumps required to pass the cascade, Frey Creek Cascades was likely a passage barrier under the observed flow conditions.

Assessment at high flow condition: Although the Frey Creek Cascades pictured above was not evaluated at a representative high flow condition, the high water mark illustrated in Figure 5.5-23 suggests that under full pool conditions, this portion of the cascade complex would be inundated, and therefore potentially passable. Additional cascades immediately upstream of the location in the photograph that are above the high pool of the reservoir were judged to be impassable fish barriers in this typically high gradient stream. Therefore Frey Creek Cascades was determined to be likely impassable for all four salmonids evaluated under the flow conditions observed.

5.5.10 McCabe Creek

Description: McCabe Creek is a cascading stream over bedrock step-pools, which is a tributary to the South Fork Feather River. McCabe Creek Falls is a two-step waterfall with a base pool at the high water mark of Lake Oroville (elevation 900'). The total height of the falls is approximately 23 ft, with the upper portion of the falls comprising of a vertical drop of approximately 5 ft. The lower portion of the falls consists of an angled bedrock waterslide that is roughly 18 ft high. The estimated total horizontal run of McCabe Falls is approximately 23 ft. The pool at the base of the waterfall is about 5 ft deep.

Assessment at low flow condition: Because DWR was unaware that McCabe Falls could potentially be a barrier to anadromous salmonid upstream migration, the falls were not evaluated at a representative low flow. However, because flows during the summer in McCabe Creek are substantially lower than those observed during the spring (E. See, DWR, pers. comm.), it is likely that McCabe Creek Falls is a passage barrier to all anadromous salmonids under low flow conditions.

Figure 5.5-24. McCabe Creek Falls on July 31, 2002.

Assessment at high flow condition: DWR biologist Eric See evaluated McCabe Creek Falls during Spring 2003 to assess a representative high flow on McCabe Creek (E. See, DWR, pers. comm.). The conditions at McCabe Creek Falls during the evaluation are illustrated in Figure 5.5-24. Because McCabe Creek Falls is an angled bedrock slide below a 5 ft vertical drop, and based on the lack of staging and landing areas an anadromous salmonid would need to navigate above such a slide, it was determined to be likely impassable for all four salmonids evaluated under the flow conditions observed.

6.0 ANALYSES

6.1 EXISTING CONDITIONS/ENVIRONMENTAL SETTING

As a subtask of SP-F3.1, *Evaluation of Project Effects on Fish and Their Habitat within Lake Oroville, its Upstream Tributaries, the Thermalito Complex, and the Oroville Wildlife Area*, the characterization and assessment of potential fish passage barriers in Task 1A fulfills a portion of the FERC application requirements by detailing the potential effects of project operations on fish passage into upstream tributaries. Additionally, the results of Task 1A of SP-F3.1 define the upstream geographic extent of several direct effects study plans extending upstream of Lake Oroville, and provides information regarding the ability of the fish occurring within Lake Oroville to access habitat upstream of Lake Oroville and to interact with the fish communities in the tributaries upstream from Lake Oroville. In addition to fulfilling these requirements, information collected during this task may be used in developing or evaluating potential Resource Actions.

Ongoing operation of the Oroville Facilities has the potential to influence accessibility to upstream tributary habitat and the opportunity for interactions between tributary and Lake Oroville fishes. Operations of the Oroville Facilities affect the water surface elevation of Lake Oroville, and the water surface elevation of Lake Oroville influences the ability of Lake Oroville fish to migrate into upstream tributaries. The results of this study provide information regarding the ability of the fish occurring within Lake Oroville to access habitat upstream of Lake Oroville, and identifies previously undocumented fish passage barriers in tributaries to Lake Oroville.

6.2 PROJECT-RELATED EFFECTS

The passage barrier expert team provides the following conclusions resulting from implementation of the potential passage impediment assessment:

- Because of the hydrologic conditions exhibited during the October 2002 and March 2003 passage barrier assessments and the limited data set, the conclusions of this investigation only serve as an illustration of potential barrier characteristics during representative low and high flows, and may not be interpolated to extreme flow and/or reservoir pool conditions.
- The passage barrier assessment provides a substantial amount of information related to the potential migratory boundaries of 4 major and 10 minor tributary streams within the upstream drainages of Lake Oroville. Table 6-1 provides the descriptive locations and Global Positioning System (GPS) coordinates for likely migratory boundaries in each of the evaluated streams. In each case, the migratory boundary is the most likely passage barrier within the drainage above the Lake Oroville full-pool elevation.

Table 6-1. Physical and geographic location of the most likely migratory boundary within the 14 streams evaluated during the potential passage barrier assessment.

Stream	Physical Description of Fish Passage Barriers	Approx. GPS Coordinates
West Branch of the North Fork Feather River	Salmon Falls located approximately 2 to 3 miles upstream of the confluence between the West Branch of the North Fork Feather River and Concow Creek at an elevation of approximately 1148 feet	39° 45.897 -121° 33.778
North Fork Feather River	Big Bend Dam is only potentially passable during times of reservoir full pool	39° 48.639 -121° 25.846
Middle Fork Feather River	Bald Rock Falls located approximately 1 mile upstream of the confluence between the Middle Fork Feather River and the Fall River, within Bald Rock Canyon	39° 38.806 -121° 17.653
South Fork Feather River	Ponderosa Dam	39° 33.010 -121° 18.229
Dark Canyon Creek	Dark Canyon Creek appears unsuitable for salmonids due to the deposition of vast amounts of sediment	39° 41.36 -121° 29.33
Concow Creek	The waterfall existing approximately 15 feet above the full-pool elevation of Lake Oroville	39° 43.355 -121° 33.127
Berry Creek	The waterfall located approximately 75 yards upstream of the full-pool elevation of Lake Oroville	39° 39.927 -121° 25.492
French Creek	The waterfall located approximately 1 mile upstream of the confluence between French Creek and the North Fork arm of Lake Oroville (during a reservoir pool of 828 feet)	39° 41.767 -121° 23.1
Chino Creek	The waterfall located approximately 150 yards upstream of the interface between Chino Creek and the Lake Oroville full-pool level	39° 43.134 -121° 25.36
Stony Creek	Stony Creek was dry during the barrier assessment	39° 43.255 -121° 25.837
Sucker Run Creek	The cascade/falls complex located approximately 1 mile upstream of the interface between Lake Oroville and Sucker Run Creek (during October 2002 reservoir pool conditions)	39° 33.232 121° 18.403
Fall River	Fall River Falls located approximately 125m upstream of the high water mark of Lake Oroville	39° 38.4 -121° 16.8
Frey Creek	Frey Creek Cascades located near the interface between Lake Oroville and Frey Creek (during July 2002 reservoir pool conditions)	39° 37.8 -121° 16.8
McCabe Creek	The waterfall located proximate to full-pool elevation of Lake Oroville	39° 31.2 -121° 20.7

7.0 REFERENCES

Alaska Department of Fish and Game and Alaska Department of Transportation and Public Facilities. 2001. Memorandum of Agreement Between Alaska Department of Fish and Game and Alaska Department of Transportation and Public Facilities for the Design, Permitting, and Construction of Culverts for Fish Passage. 1-33.

Bell, M. C. 1973. Fisheries Handbook of Engineering Requirements and Biological Criteria. Portland, OR: U.S. Army Engineering Division, North Pacific Corps of Engineers.

Bell, M. C. 1991. Fisheries Handbook of Engineering Requirements and Biological Criteria. Sacramento, CA: U. S. Army Corps of Engineers, Fish Passage Development and Evaluation Program.

Bjornn, T. C. and D. W. Reiser. 1991. No. American Fisheries Society Special Publication 19. Habitat Requirements of Salmonids in Streams *in* Influences of Forest and Rangeland Management of Salmonid Fishes and their Habitats. Meehan, W. R. (ed.), pp. 83-138.

Dauble, D. D. and R. P. Mueller. 1993. Factors Affecting the Survival of Upstream Adult Migrant Salmonids in the Columbia River Basin. BPA Report DOE/BP-99654-9. U.S. Department of Energy, Bonneville Power Administration, Division of Fish and Wildlife, Project No. 1993-013, Contract No. DE-AM79-1993BP99654, Master Agreement DE-AI79-BP62611.

DFG. 1952. Fisheries Problems of the Feather River With Special Reference to the Proposed Oroville Dam.

DFG. 2002. Status Review of California Coho Salmon North of San Francisco- Report to The California Fish and Game Commission. Candidate Species Status Review Report 2002-3. Department of Fish and Game.

DWR. 1983. Concerning the Operation of the Oroville Division of the State Water Project for Management of Fish and Wildlife: Agreement Between the California Department of Water Resources and the California Department of Fish and Game- unpublished work.

DWR. 1993. Lake Oroville Fisheries Management Plan. Progress Report.

DWR. 1999. 1999 Lake Oroville Annual Report of Fish Stocking and Fish Habitat Improvements. FERC Project No. 2100-054.

English, K. K., C. Sliwinski, B. Nass, and J. R. Stevenson. 2001. Assessment of Adult Steelhead Migration Through the Mid-Columbia River Using Radio-Telemetry Techniques, 1999-2000.

Environmental Protection Information Center, Center for Biological Diversity, and WaterKeepers Northern California. June 2001. Petition to List the North American Green Sturgeon As an Endangered or Threatened Species Under the Endangered Species Act.

FERC. 2001. Conservation of Power and Water Resources. 18 CFR 4.51.

Froese, R. and D. Pauly. Accessed on October 15, 2002a. *Acipenser medirostris*-Green Sturgeon. Available at www.fishbase.org

Froese, R. and D. Pauly. Accessed on October 15, 2002b. Chinook Salmon-*Oncorhynchus tshawytscha*. Available at www.fishbase.org

Hoar, W. S. and D. J. Randall. 1978. Fish Physiology. Academic Press New York,

Hunter, L. A. and L. Mayor. 1986. Analysis of Fish Swimming Performance Data.

Moyle, P. B. 2002. Inland Fishes of California. Berkeley: University of California Press,

Moyle, P. B., R. M. Yoshiyama, J. E. Williams, and E. D. Wikramanayake. 1995. Fish Species of Special Concern in California. Sacramento, CA: California Department of Fish and Game,

NOAA. 1998. Final Rule: Notice of Determination. Endangered and Threatened Species: Threatened Status for Two ESUs of Steelhead in Washington, Oregon, and California. Federal Register 63(53):13347-13371. March 19, 1998

NOAA. 1999. Endangered and Threatened Species; Threatened Status for Two Chinook Salmon Evolutionarily Significant Units (ESUs) in California; Final Rule. Federal Register 50(223):50394-50415. September 16, 1999

NOAA. 2003. Endangered and Threatened Wildlife and Plants; 12-Month Finding on a Petition to List North American Green Sturgeon As a Threatened or Endangered Species. Federal Register 50(223-224):4433-4441. January 29, 2003.

Oregon Fish Commission. 1960. Results of Tagging Program to Enumerate the Numbers and to Determine the Seasonal Occurrence of Anadromous Fish in the Snake River and Its Tributaries. Portland, Oregon: U.S. Army Corps of Engineers, North Pacific Division.

Powers, P. D. and J. F. Orsborn. 1985. Analysis of Barriers to Upstream Migration: An Investigation of the Physical and Biological Conditions Affecting Fish Passage Success at Culverts and Waterfalls. BPA Report DOE/BP-36523-1.

See, E. Quick L. Oro Bass Spawning Facts, Email Communication. 2001.

Yoshiyama, R. M., F. W. Fisher, and P. B. Moyle. 1998. Historical Abundance and Decline of Chinook Salmon in the Central Valley Region of California. North American Journal of Fisheries Management 18:487-521.